OPTIMUM IMPLEMENTATION OF SMALL-SCALE COMBINED HEAT AND POWER PLANT IN UK HOTEL BUILDINGS: A CASE STUDY

by

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2 ABSTRACT

The worldwide tourism and travel industry, of which the provision of hotel accommodation forms a major part, is increasingly under pressure to improve its environmental performance. A number of key drivers are responsible. The sector is becoming aware that climate change represents a threat to its continued economic well being, and new hotel developments in the UK are being asked to meet increasingly strict environmental targets. At the same time, the rising cost of energy and consumer pressure to 'go green' are providing incentives to hotel operators to cut energy demand and reduce the carbon emissions from their buildings. As a result, the use of low and zero-carbon (LZC) energy technologies is becoming attractive to hotel companies. Small-scale combined heat and power (CHP) systems are experiencing a resurgence in the UK market as an important design option for lowering greenhouse gas (GHG) emissions from buildings. To date, however, there appear to be no wide ranging post-occupancy studies on the performance of small-scale CHP units specifically in hotel buildings. This report investigates the use of small-scale CHP plant in a UK case study hotel and seeks to quantify the contribution that the unit makes to improving the building's environmental performance. The reduction in carbon footprint and utility costs resulting from the use of CHP plant is assessed, and options for improving the emissions rating of the building are explored. The results of the case study evaluation are extrapolated to enable a wider discussion of how CHP can be optimally implemented in hotel buildings. Opportunities for further research are also identified.

3 DRIVERS FOR CHANGE IN THE HOTEL INDUSTRY

The construction and management of hotel buildings forms an essential part of the international tourist trade, a sector which is experiencing rapid growth both in the UK and worldwide. Hotel operators have often come under criticism in the past for their handling of environmental issues relating to their business operations, but a number of key drivers are now contributing to a sea change in attitudes.

3.1 Growth in the Hotel Industry

Many countries rely on tourism and its related activities, such as the provision of hotel accommodation, as a key component of their economies. Global tourism was estimated by the WTO[1] to be worth $733 billion in 2006, with 75 countries earning 'more than $1 billion from international tourism' (United Nations World Tourism Organization 2008b).

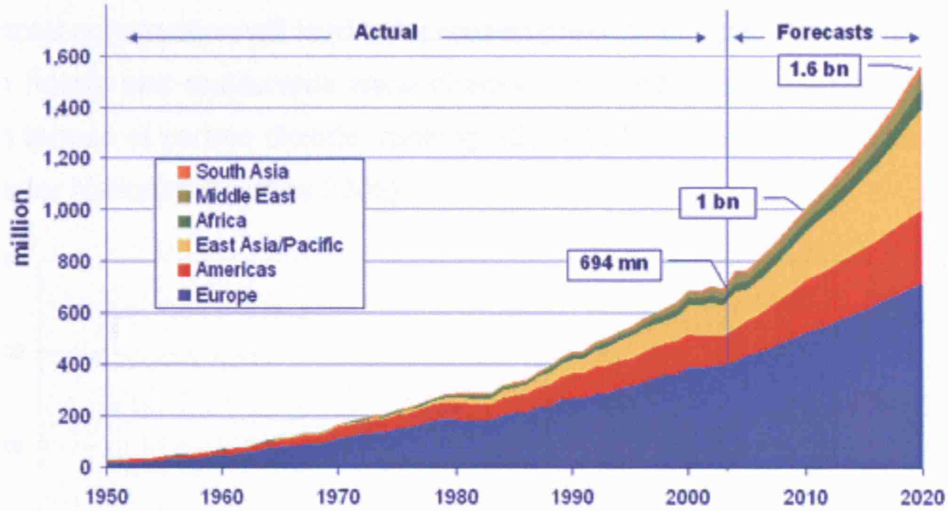

Figure 1 – Actual and Predicted Growth in International Tourist Arrivals from 1950 – 2020 (United Nations World Tourism Organization 2008a)

The importance of tourism to the global economy is only set to increase as traveller numbers rise. Figure 1 illustrates the explosive growth in international visitor numbers, which have expanded from under 20 million in 1950 to 846 million in 2006. This figure is projected to grow 89% to 1.6 billion in 2020 (United Nations World Tourism Organization 2008b). The WTTC[2] claims that by 2018 the world tourist industry will support 297 million jobs and represent 10.5% of global GDP (World Travel & Tourism Council 2007). This global increase in travel will undoubtedly lead to new demand for hotel buildings.

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[1] WTO, United Nations World Tourism Organization, www.unwto.org

[2] WTTC, World Travel & Tourism Council, www.wttc.org

The hotel business in the United Kingdom already contributes significantly to the national economy[3], and is also a strong growth area for hotel construction, with industry commentators predicting that the sector will 'expand by nearly 8%' in the period 2007 – 2009 (PKF 2007). During 2001-2006, the British hotel industry invested '£3bn a year' in hotel developments, with new hotels opening at a rate of around 150 annually (British Hospitality Association 2007).

New hotel construction will lead to increased greenhouse gas emissions. In 2006, British hotels and restaurants were directly responsible for generating over 2.5 million tonnes of carbon dioxide, ranking 35th out of a list of 93 economic sectors (Office for National Statistics 2006).

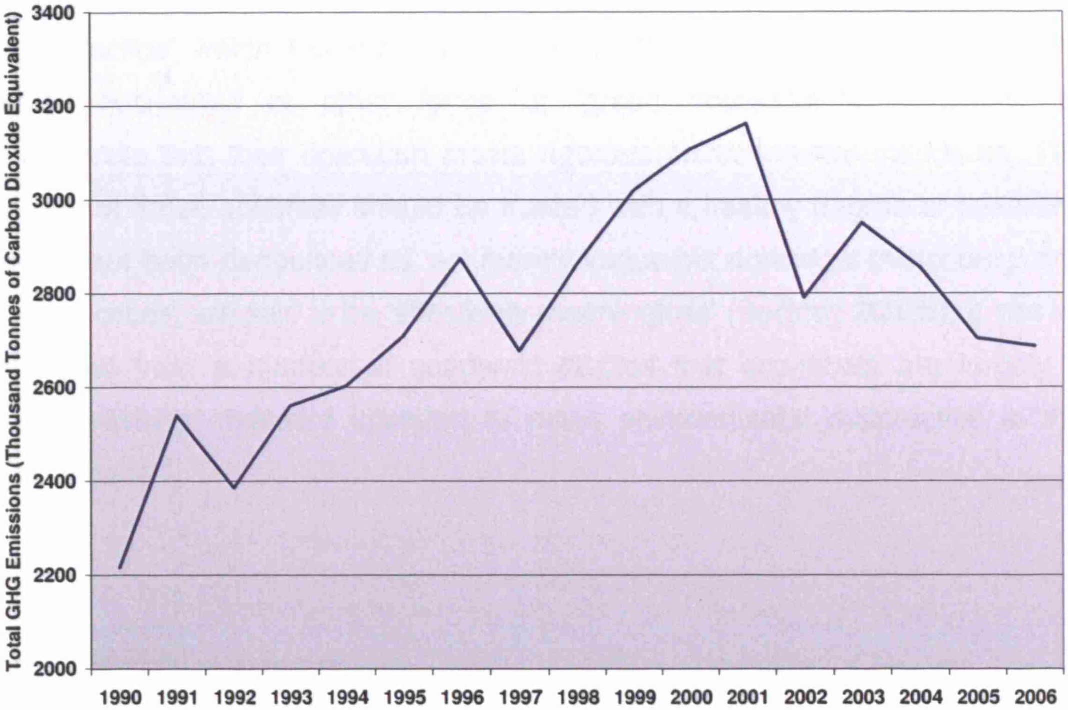

Figure 2 – Annual Variations in Total Greenhouse Gas Emissions for the Hotel and Restaurant Sector, 1990 – 2006 (Office for National Statistics 2006)

[3] The UK received 32m overseas visitors in 2006, 'spending over £15bn', with domestic holidays and business travel also contributing £11 billion and £5 billion respectively (British Hospitality Association 2007). This represents a combined total spend of £31 billion.

Figure 2 shows that emissions from British hotels rose approximately 45% between 1990 and 2000, but have been falling since the turn of the century at an annual average rate of 3% between 2001 and 2006. Global tourism experienced a decline in the wake of the 2001 September 11th terrorist attacks, which resulted in a downturn in international air travel (Makinen 2002). It seems likely, therefore, that the recent reduction in emissions levels is due to a short term decline in economic activity rather than as a result of improving environmental standards. The growth in the construction of new hotel properties means that emissions from the sector will continue to rise unless preventative action is taken.

Historically, hotel operators have not been leaders in setting environmental standards. Indeed, it has been said that 'much lip service is paid to environmental good practice' within the industry (Stipanuk 1996). Many hotels are keen to display eco-labels or other forms of 'green accreditation', intending to demonstrate that their operation meets rigorous environmental standards. The majority of these schemes should be treated with a healthy degree of cynicism. Some have been denounced as 'not merely vague but downright misleading' and in some cases, are said to be 'effectively meaningless' (Buckley 2002b). It can be concluded from a number of academic studies that eco-labels are largely a 'green washing' measure intended to mask environmental malpractice in the hotel industry[4].

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[4] Lax enforcement of eco-label reporting standards by their awarding bodies means that many hotels continue to display their accreditation despite not having published any data on their environmental performance (Font 2002). Commentators note that eco-labels 'are generally far less effective than simple government actions such as building codes or permits to operate' (Buckley 2002a), and that 'green accreditation schemes alone may be insufficient to promote more sustainable environmental practices in the tourism industry' (Warnken, Bradley & Guilding 2005).

The status quo cannot continue. The remainder of this section of the report discusses how the hotel industry in the UK is now coming under pressure to make concrete improvements to environmental performance. Hotel operators now find themselves exposed to a complex set of drivers which favour a reduction in overall energy consumption and the associated carbon emissions from their buildings. These factors are beginning to affect the way hotels are designed, constructed, managed and operated. Many hotel operators are interested in finding ways to reduce their environmental impact by employing low and zero-carbon (LZC) systems in their buildings, such as combined heat and power (CHP) generation plant, which will be discussed in more detail in Section 4 (page 21).

3.2 The Impact of Climate Change and Planning Policies

The IPCC[5] states that 'warming of the climate system is unequivocal', and that there is a greater than 90% probability that the 'increase in global average temperatures since the mid-20th century' is due to the 'increase in anthropogenic GHG concentrations' (Intergovernmental Panel on Climate Change 2007).

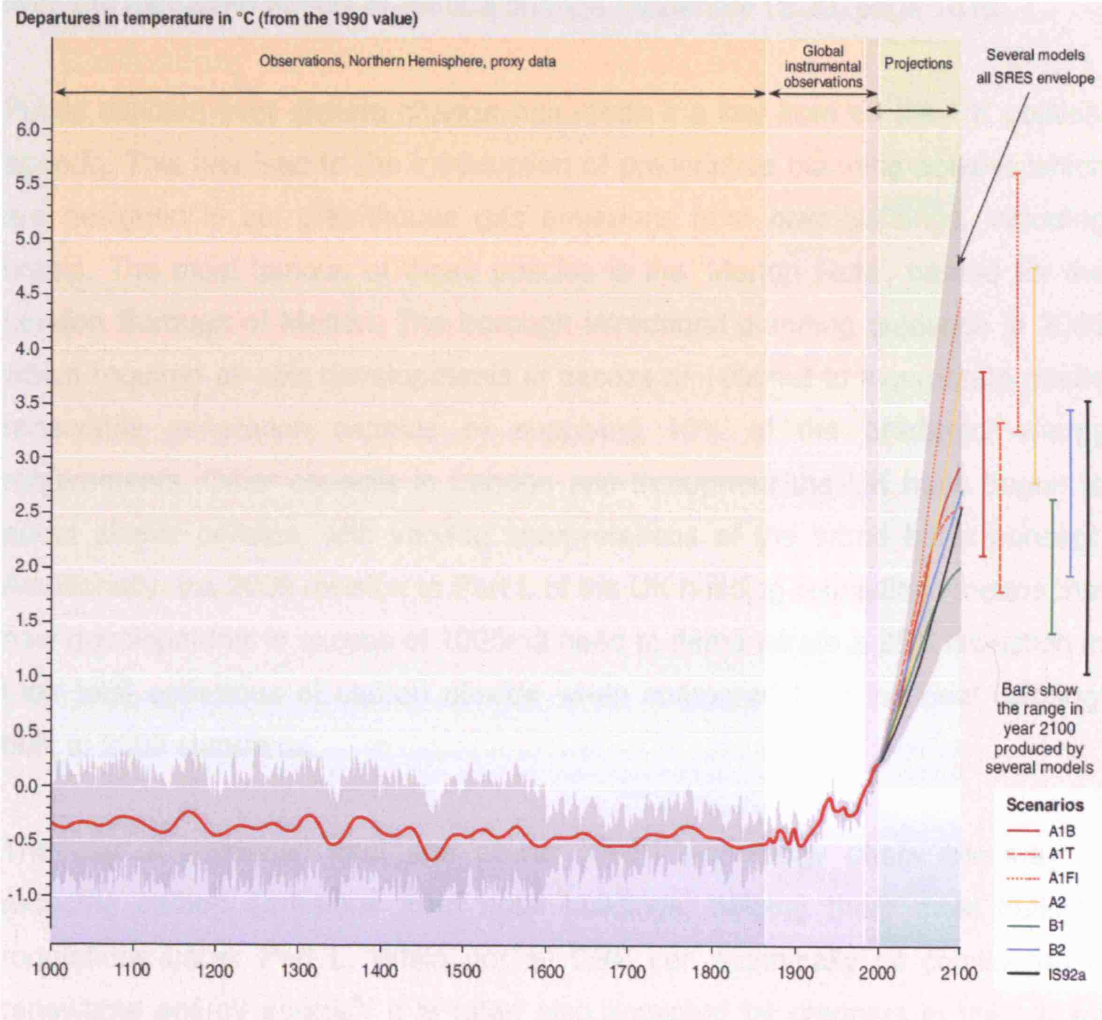

Figure 3 – Variations of the Earth's Surface Temperature, Years 1000 to 2100 (Intergovernmental Panel on Climate Change 2001)

Figure 3 above contains the famous 'hockey stick' graph, widely popularised by the 2006 documentary 'An Inconvenient Truth', illustrating how global

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[5] IPCC, Intergovernmental Panel on Climate Change, www.ipcc.ch

temperatures are projected to rise above 1990 levels under a variety of different IPCC emissions scenarios. While there is an element of uncertainty between the different projections, it is clear that significant warming of the global climate system is occurring and will continue to occur. Many hotel operators are beginning to recognise that the economic viability of their businesses is at risk from the damaging effects of climate change (Appendix 12.23, page 161).

Public concern over climate change has made it a key item on the UK political agenda. This has lead to the introduction of prescriptive planning policies which are designed to cut greenhouse gas emissions from new buildings, including hotels. The most famous of these policies is the 'Merton Rule', named for the London Borough of Merton. The borough introduced planning guidance in 2003 which required all new developments in excess of 1000m2 to incorporate onsite renewable generation capable of supplying 10% of the predicted energy requirements. Other councils in London and throughout the UK have begun to adopt similar policies, with varying interpretations of the same basic concept. Additionally, the 2006 revision to Part L of the UK building regulations means that new developments in excess of 1000m2 need to demonstrate a 25% reduction in their total emissions of carbon dioxide when compared to a 'notional building' built to 2002 standards.

The use of combined heat and power (CHP) technology offers one way of reducing carbon emissions from hotel buildings, helping them meet building regulations under Part L. While not all CHP can technically be considered a renewable energy source[6], it is often also accepted by planners in the UK as contributing towards Merton Rule-style targets. In London, the GLA[7] also mandates that local councils consider the use of CHP in all new developments

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[6] The classification of CHP plant as a renewable energy source depends on the fuel used in the combustion process. This is discussed in more detail in Section 4 (page 21).

[7] Greater London Authority, www.london.gov.uk/

where viable, irrespective of other planning requirements. This is laid out in the Mayor of London's own Energy Strategy document, which requires that 'planning applications referable to him (must) include CHP and community heating where viable' and that 'boroughs should expect the same' (Greater London Authority 2004). Combined heat and power technology and its applicability to hotel buildings is detailed in Section 4 (page 21).

3.3 The Impact of Rising Energy Prices

The price of oil has increased every year for the last seven years, representing 'the longest period of rising prices on record' (BP 2008). The cost of natural gas and other energy commodities are strongly linked to oil prices by a variety of market mechanisms (Hartley, Medlock & Rosthal 2008). This means that increasing oil prices generally lead to strong rises in the cost of energy. Recent price increases have sent shocks through the world economy. As early as 2005, the IEA[8] stated that high oil prices were already causing 'new cries of alarm in consuming countries' (International Energy Agency 2005).

	Yearly Basket Price
1995	16.86
1996	20.29
1997	18.68
1998	12.28
1999	17.48
2000	27.6
2001	23.12
2002	24.36
2003	28.1
2004	36.05
2005	50.64
2006	61.08
2007	69.08
2008	103.84

Figure 4 – OPEC[9] Historical Data, Yearly Average Price of Crude Oil, US Dollars per Barrel, (Organization of the Petroleum Exporting Countries 2008)

Figure 4 shows that the yearly average price of crude oil quadrupled between 1995 and 2007. As of July 2008, the price of oil is hovering around $130 a barrel, with the average price for 2008 so far being $103.84 per barrel. IEA modelling forecasts average price rises of 17% between 2012 and 2030 (International Energy Agency 2006). These wholesale price rises will be even higher when

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[8] IEA, International Energy Agency, www.iea.org

[9] OPEC, The Organization of the Petroleum Exporting Countries, www.opec.org

passed on to consumers, as energy providers need to add their transportation, processing and generation costs, as well as turn a profit from their operations.

Price volatility in the energy markets is likely to continue right up to 2030 (International Energy Agency 2006). This means that while a 17% average rise in energy prices is predicted in the long term, it is almost impossible to determine what dramatic spikes may occur over shorter term periods. As an example, some industry commentators are predicting oil prices as high as $200 per barrel within the next two years (Goldman Sachs 2008), which if true, would represent a short term increase of 90% relative to the average annual price for 2007. Hotels, like any other business, need to buy their electricity and gas from energy providers, and will be affected by these price fluctuations.

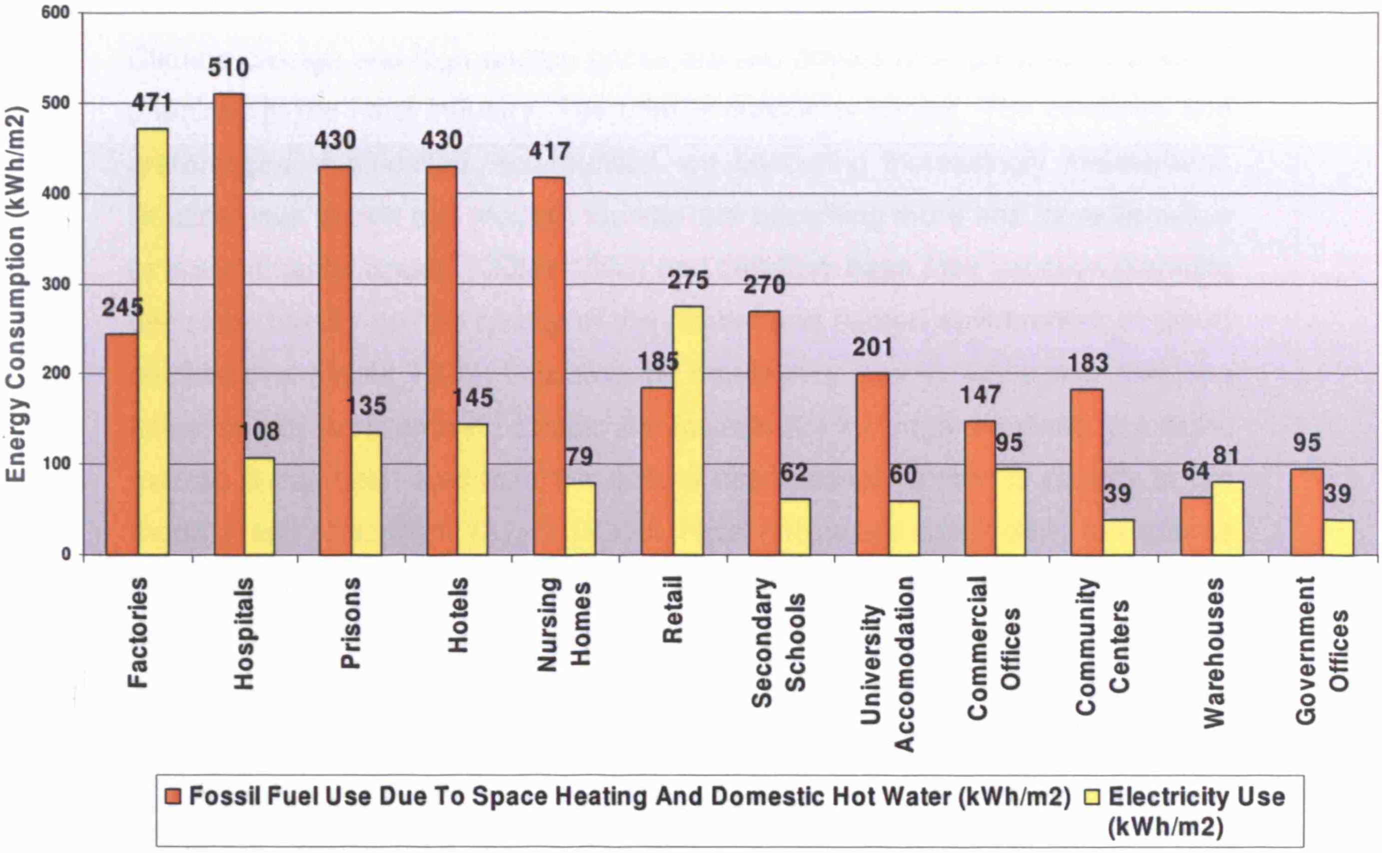

Figure 5 – Comparison of Energy Consumption Benchmarks for Different Building Types in the United Kingdom (for a full list of sources, see Appendix 12.22, page 159)

Figure 5 shows that UK hotels are actually highly energy intensive enterprises, comparable to prisons, hospitals, and nursing homes, all of which have high fossil energy requirements due to demand for space heating and hot water. Due to their high energy requirements, large increases in fuel costs have the potential to significantly impact on the profitability of hotel operations. Out of pure financial necessity, hotels will be increasingly under commercial pressure to both consume less energy, and to use the energy they do consume more efficiently. Small-scale combined heat and power (CHP) plant offers one method for hotel operators to heat and power their buildings in a more energy efficient manner, helping to mitigate the impact of price rises on bottom line profits. The use of CHP in hotel buildings is discussed in more detail in Section 4 (page 21).

3.4 The Impact of Environmental Consumerism

Climate change and high energy prices are two drivers prompting more efficient practices in the hotel industry. The third is consumer choice. The concerns and preferences of so-called 'eco-tourists' are becoming increasingly mainstream. Studies have shown that modern tourists 'are becoming more and more sensitive to environmental issues' (Gülez 1994) and that they base their vacation planning decisions heavily on 'the quality of the natural and human environment of resort destinations' (Ayala 1995), including the hotels they stay in. Consumer attitudes influenced by or resembling classic eco-tourism are no longer confined to a niche market. It has been said that 'the bulk of international tourism is already in the mode of soft ecotourism' (Ayala 1996b). Hotel chains are now looking to espouse their environmental credential in order to capitalise on this trend, the business prospect of which 'appears enormous' (Ayala 1996a). Put simply, it is in the interest of hotel operators to appear 'green' in order to attract more business. As early as 1994, it was argued that 'hotel properties where practices are environmentally sensitive will have an advantage in the marketplace over rival properties' (Iwanowski & Rushmore 1994).

Operating a 'greener' building is a powerful marketing strategy for attracting more environmentally-concerned customers. As well as realising immediate financial savings through improvements in energy efficiency and waste management[10], there is even evidence to support the view that hotel companies can charge more for guests to stay at a 'greener' hotel. A recent Australian study found that more than 50% of those questioned responded positively to the idea of more 'environmentally friendly accommodation' and that 49% of respondents were

[10] A 1999 study into environmental management processes in the US lodging industry concluded that 'operating a "green" hotel is not only good practice, but good business', with one hotel saving between $77,000 and $91,000 annually in the first two years of implementing an environmental management programme (Enz & Siguaw 1999).

willing to pay 'between 1% and 5%' extra for accommodation that incorporated some form of renewable energy supply (Dalton, Lockington & Baldock 2008).

As well as marketing 'greener' buildings in response to consumer preferences, the hotel industry is also being forced to 'go green' by stakeholders and other third parties. The ITP[11] states that 'shareholders, investors, employees, customers, environmental and ethical groups - and the general public - expect companies to be exemplary across the "triple bottom line" of economic, social and environmental management.' The ITP notes ominously that if hotels are found wanting in any of these areas, then 'pressure groups and the media are willing and able to expose their weaknesses' (International Tourism Partnership 2007). Hotels which do not act to improve their environmental performance risk attracting a large degree of negative publicity. In this climate, 'the industry is gradually deeming it wiser to police itself rather than to be policed' (Marin & Jafari 2002).

Large hotel companies such as the Rezidor Hotel Group and Hilton Hotels Corporation are committing themselves to reducing their environmental impact. On the 5th June 2008 Hilton announced details of a five-year plan for 2009 to 2014, setting reduction targets of 20% in the areas of both CO2 emissions and energy consumption (Hilton Hotels Corporation 2008). The Rezidor Hotel Group has a long term strategic objective to 'reduce dependence on fossil fuels and become more energy efficient in all areas of operation', and is one of the few hotel chains to publish a regular annual sustainability report. The company aims to increase its use of carbon-neutral energy sources and was determined to reduce its energy consumption by 5% per guest-night in 2007 (The Rezidor Hotel Group 2008a).

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[11] ITP, International Tourism Partnership, formerly IHEI, International Hotels Environment Initiative, www.tourismpartnership.org

Hotel chains are beginning to market themselves as environmental champions and make concrete commitments to reducing their carbon emissions. In order to do so, they will need to invest more in efficient building services in their properties, including so-called low and zero-carbon (LZC) systems. One important option is small-scale CHP. This offers an attractive proposition for hotel owners, as it is based on mature and reliable combustion engine technology, and can be employed both in new hotels and as a retrofit option for existing building stock. Small-scale CHP technology and its applicability to hotel buildings are discussed in more detail in Section 4 (page 21).

4 SMALL-SCALE COMBINED HEAT AND POWER IN HOTELS

This section gives a brief overview of small-scale combined heat and power (CHP) technology, the prospects for its future expansion in the UK, and its application in hotel buildings.

4.1 Demand for Low and Zero-Carbon (LZC) Technologies

As covered previously in Section 3 (page 7), many hotel operators are looking to:

- reduce their emissions of greenhouse gases to meet building regulations
- cut utility costs to limit their exposure to volatility in the energy markets
- improve their image in the minds of environmentally conscious consumers

These companies, by necessity, are investigating the use of so called 'low and zero-carbon' (LZC) energy technologies for use in new hotels, and potentially as retrofit options for their existing properties.

Building-related emissions of carbon dioxide are linked to the near-ubiquitous use of fossil fuels as a source of primary energy for heating, lighting and power. Low and zero-carbon (LZC) technology is a catch-all phrase for systems which either:

- use fossil fuel energy in a significantly more efficient manner than conventional plant (low-carbon)

or

- harness power from truly renewable sources, such as solar and wind energy (zero-carbon)

Combined heat and power (CHP), is an important low-carbon technology which is of particular relevance to hotel buildings due to their high heat demand density.

4.2 Combined Heat and Power Explained

Combined heat and power (CHP) involves the generation of electricity and useful heat in a single process, and is widely employed with a variety of different combustion fuels such as diesel, natural gas, heavy oils and even renewable biomass. The crucial difference between CHP and conventional electricity generation is that the heat from the combustion process is recovered and used, rather than being rejected to atmosphere and wasted.

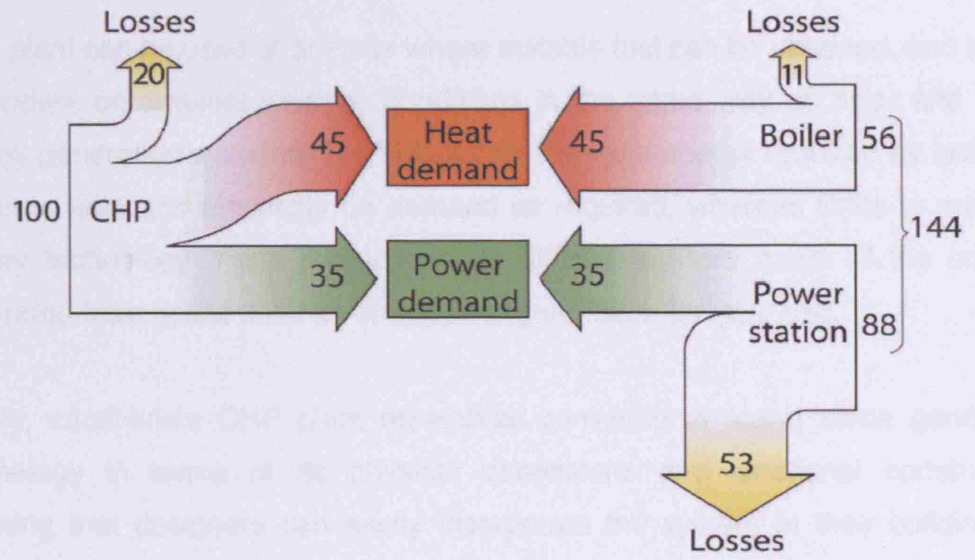

Figure 6 – Sankey Diagram Showing Inputs/Outputs for a Typical CHP Plant vs. a Conventional Boiler and Power Station (Action Energy 2004)

Figure 6 illustrates the typical output from a CHP unit compared with the equivalent arrangement using a conventional power station and boiler. It can be seen that the conventional generation scenario needs 44% more fuel than the CHP system to meet the same power and heat demands. CHP clearly makes better use of the primary fuel input, releasing 'less CO2 per kilowatt of energy supplied', enabling buildings to meet their energy needs in a way which is 'economically advantageous', 'efficient in the use of energy' and 'environmentally beneficial' (CIBSE 1999b).

4.3 Small-Scale CHP Versus Solar and Wind Energy Sources

CHP using conventional fossil fuels is considered a low-carbon technology rather than a zero-carbon technology, as it still results in the production of CO2 emissions. Currently, fossil fuel CHP remains an important low-carbon option for buildings and is often considered as a design option alongside renewable energy sources. Conventional CHP has a number of advantages over renewable sources reliant on solar or wind energy.

CHP plant can be used at any site where suitable fuel can be obtained, and is not dependent on ambient weather conditions in the same way as solar and wind energy generation systems. CHP plant can store the energy required as fuel and generate heat and electricity on demand as required, whereas limits to modern battery technology mean that it is often difficult to store much of the energy generated from onsite solar or wind power generation for later use.

Finally, small-scale CHP plant resembles conventional stand alone generator technology in terms of its physical dimensions and locational constraints, meaning that designers can easily incorporate the system in their building by positioning it on the roof or in a basement. CHP plant will therefore rarely have an impact on the architectural vision for the building. By contrast, many renewable technologies, such as building-integrated photovoltaics, are much more demanding in terms of their positioning and orientation. The limitations that these requirements place on the building design team mean that renewable energy systems are often difficult to employ in some developments. CHP plant, on the other hand, is easier to apply in a wider range of situations.

4.4 Future Prospects for CHP

Despite the projections for fuel price rises covered in Section 3.3 (page 15), the IEA predicts that 'fossil energy will remain dominant until 2030' (International Energy Agency 2006). Fossil-fired CHP will therefore continue to have a role to play in reducing emissions of carbon dioxide well into the foreseeable future.

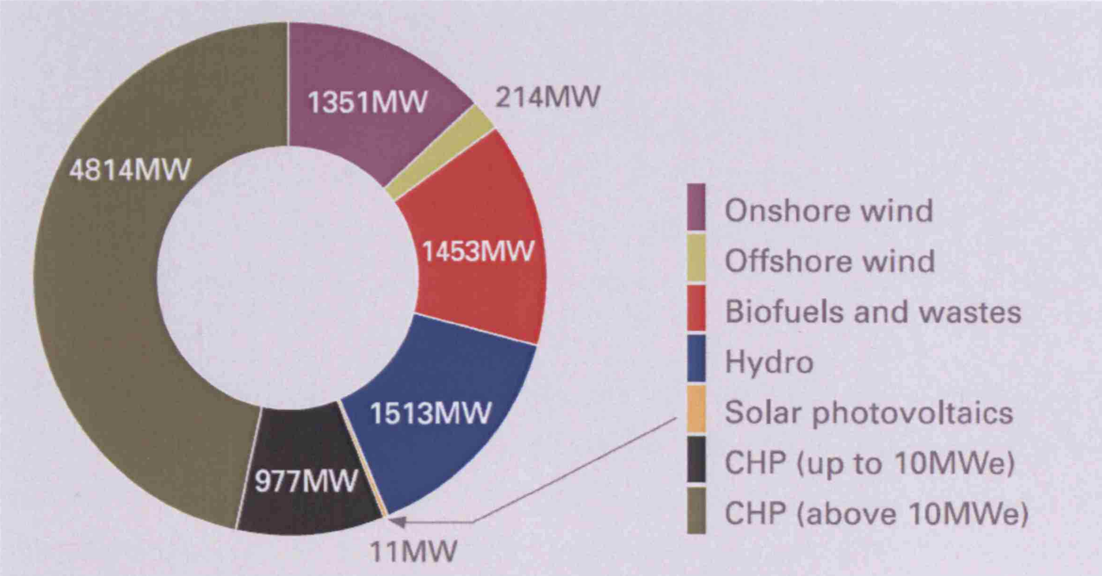

Figure 7 – UK CHP and Renewable Generation Capacity, 2006 (Department of Trade and Industry 2007)

In the UK, CHP already forms over half of the country's distributed generation capacity, as shown in Figure 7. The government is keen to continue promoting the uptake of CHP as part of their distributed generation strategy outlined in the 2007 Energy White Paper (Department of Trade and Industry 2007). CHP capacity in buildings has already 'doubled within the last decade' and the government has set a national target to install 10,000 MWe by 2010, which 'could produce around 20% of the Kyoto carbon savings target' (Action Energy 2004).

Future developments mean there is scope for small-scale CHP technology to become more carbon-neutral if run on sustainable biomass or bio-fuels. Hydrogen fuel cell CHP, while not a mature enough technology at present to have been widely commercialised, is another potentially carbon-neutral implementation of the CHP concept[12]. Another promising area for future growth is the use of CHP produced heat in conjunction with absorption chillers to produce chilled water for cooling, a technique commonly referred to as tri-generation. The discussion of these technologies and their current developments are, however, beyond the scope of this report.

[12] Whether or not hydrogen fuel-cell CHP can be said to be truly carbon-neutral depends largely on how the hydrogen fuel is produced and transported to the point of use. Hydrogen fuel generated using electricity from conventional centralised power stations will obviously have a carbon cost associated with its manufacture and transportation, even if it emits no CO2 at the point of use.

4.5 Application in Hotels

CHP plant ranges in scale from so called 'micro-CHP' units which are being investigated for use in individual homes, all the way up to district scale generators capable of serving an entire city. Small-scale CHP units generating under 1MWe are currently of most interest to hotel operators, and were first introduced into UK hotels in the early 1980s (Action Energy 2003). Hotels have emerged as an attractive end-use application for smaller CHP systems due to their relatively high density heat demands. Published feasibility studies have found CHP to be economically viable in hotels in many different climates, from Paphos in Cyprus (Papamarcou & Kalogirou 2001), to Seoul in South Korea (S. Oh, H. Oh & Kwak 2007), to London in the UK (Babus'Haq et al. 1990), with simple payback periods ranging from 3 -6 years.

Matching the output of a CHP unit to a building's demand characteristics is a complex technical endeavour. Heat and power demands fluctuate in different building types at various times during the day, and seasonally throughout the year. Different types and sizes of CHP engine also operate optimally at different power outputs. Some CHP units generate heat and power at a fixed rate, and will be sized to meet the base heat energy or electricity requirements of the building, while others are capable of modulating their output to meet peak demands.

It is rare for all of a building's energy requirements to be provided by CHP. Shortfalls in heat and power demand are normally made up for by running gas-fired boilers and importing grid electricity from the local network. Some CHP equipped buildings may experience an overproduction of either electricity or heat at different times of the day. These units typically export surplus electricity back to the grid, or are fitted with heat rejection plant to dump excess heat.

It is most common in the UK for hotel buildings to use CHP units with a constant output, sized to provide all or part of the base electrical demand of the building. Hotels typically use CHP plant for the primary purpose of lowering their electricity bills. The hotel will generate their own power on site by burning natural gas or another fuel, delivering electricity at a lower unit cost than the price charged by the local district network operator[13]. This is the case with the case study hotel building, which is covered in Section 5 (page 29). This unit actually runs on a 24-hour cycle because at current prices it is always cheaper for the hotel to generate electricity from the building's CHP plant than it is to buy power from the grid.

[13] Electricity companies often charge commercial electricity rates at different tariffs during the day and during the night. In some cases, it can be cheaper for hotels to buy electricity from the grid at night rather than to run their CHP units. In these cases, hotels will only operate their CHP units during the day when it is cheaper to generate power than it is to buy from the grid. At night the unit is simply switched off.

5 HOTEL CASE STUDY

This section gives an overview of the case study hotel, shown in Figure 8. Details of the building's internal layout and servicing arrangements are detailed along with a site overview enabling it to be placed in its urban context. The hotel's CHP installation is also described.

Figure 8 – Case Study Hotel, Radisson SAS Liverpool, External View Showing Main Ground Floor Entrance from Old Hall Street

5.1 Hotel Site and Neighbouring Buildings

Located in Liverpool at 107 Old Hall Street, the Radisson SAS forms part of a £46 million development which also includes a 30-storey residential tower, a fitness centre and a 13,000m2 office block, as shown below in Figure 9. While developed together as part of a single site, the individual properties are not supplied by any CHP-generated electricity or district heating connections from a central energy centre. As discussed later in Section 10 (page 77), this represents a missed opportunity, with the buildings supplied instead only by conventional utility connections.

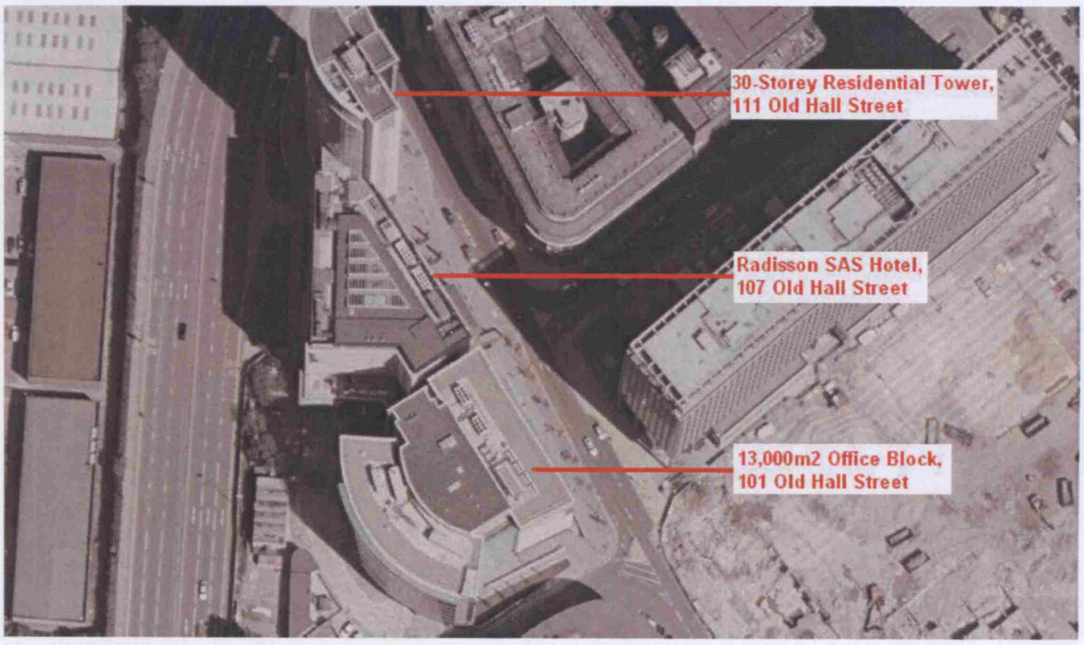

Figure 9 – Satellite Image, Old Hall Street Scheme (Google Maps 2008a)

The Radisson SAS Liverpool is part of the Rezidor Hotel Group, a chain operating a total of 237 hotels, with 85 more under development as of March 2008 (The Rezidor Hotel Group 2008c). The building opened in February 2004, and is leased from property developers The Beetham Organization. Rezidor does not actually own the building itself, but merely operates the hotel franchise. The hotel building was designed by architects Aedas and engineers Buro Happold, with Carillion as the main contractor overseeing the construction.

5.2 Hotel Layout and Facilities

The building is split into two properties, the hotel itself, and a health and fitness centre, as illustrated in Figure 10. Although hotel guests can use the gym, swimming pool, and spa facilities of the health centre, this building is considered to be a separate property, and is leased and managed independently from the actual hotel. The fitness centre has completely separate utility connections for water, gas, and electricity, and does not share any mechanical or electrical plant with the hotel. This is also a missed opportunity, as the fitness centre's swimming pool could supply a high base heat load for the CHP unit if the two were to be connected. This is explored further in Section 8.2 (page 74). Due to the separate plant and utility connections, all references to the 'hotel' in this report should be taken to mean the hotel proper, excluding the fitness centre.

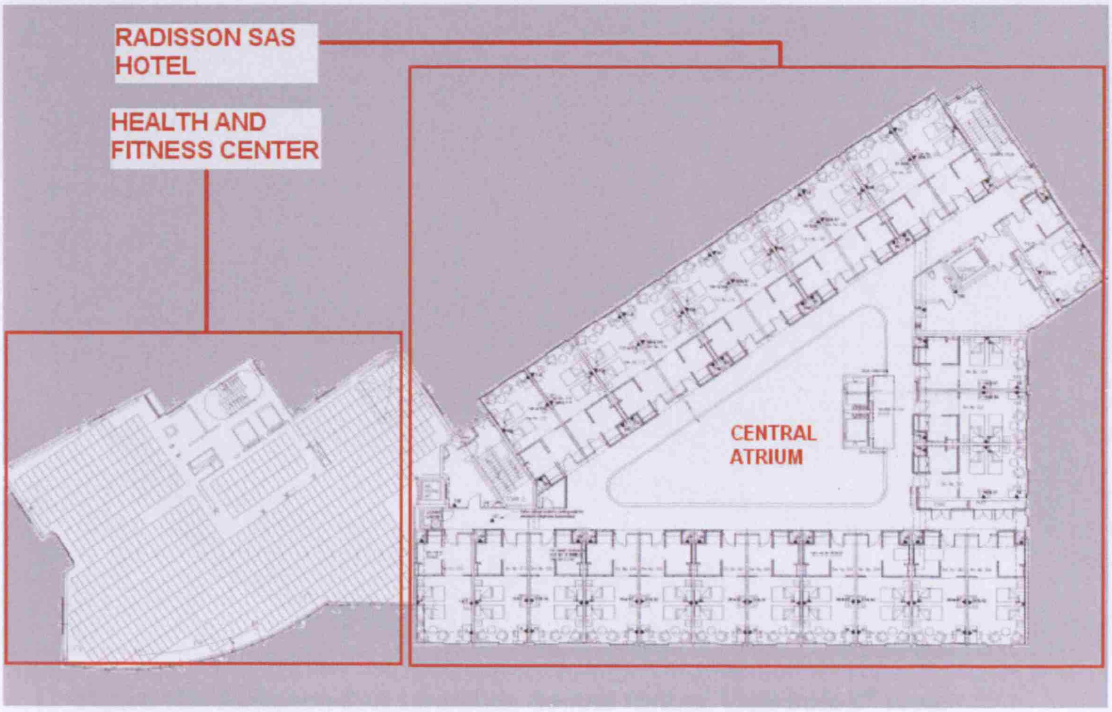

Figure 10 – Plan Layout of Building Showing Main Radisson SAS Hotel Property and Adjacent Fitness Centre

The hotel building is arranged over 10 floors with 2 basement levels, comprising just over 11,500m2 of conditioned internal floor area. The basement levels of the building are largely given over to car parking space. This does not form part of the hotel and is not accessible from the hotel premises, but is actually part of the adjacent office block at 101 Old Hall Street (Figure 9, page 30). As can be seen from Figure 10, the hotel layout is roughly triangular in shape, with the building plan articulated around a central atrium. Figure 11 shows the extent of the atrium, which runs the full height of the structure, admitting natural daylight at high level.

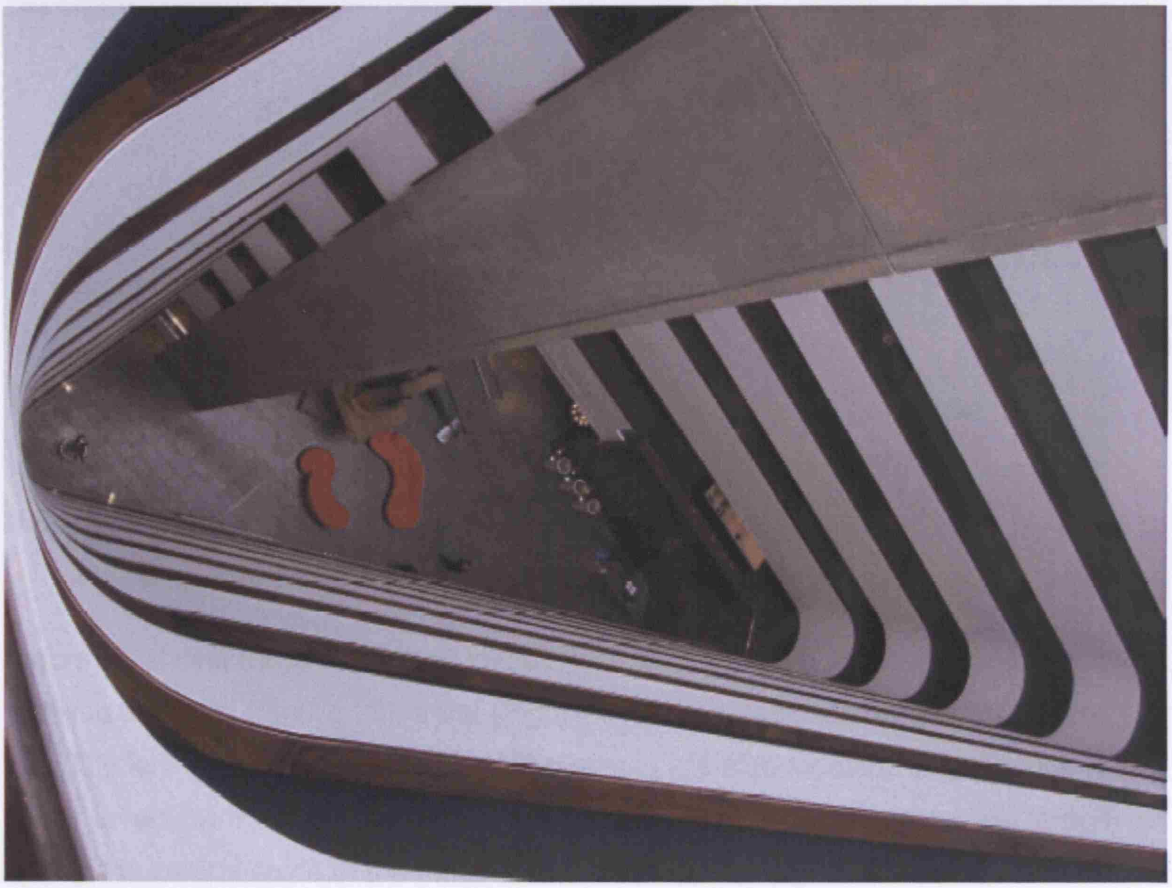

Figure 11 – Radisson SAS Liverpool, Central Atrium, View from 9th Floor

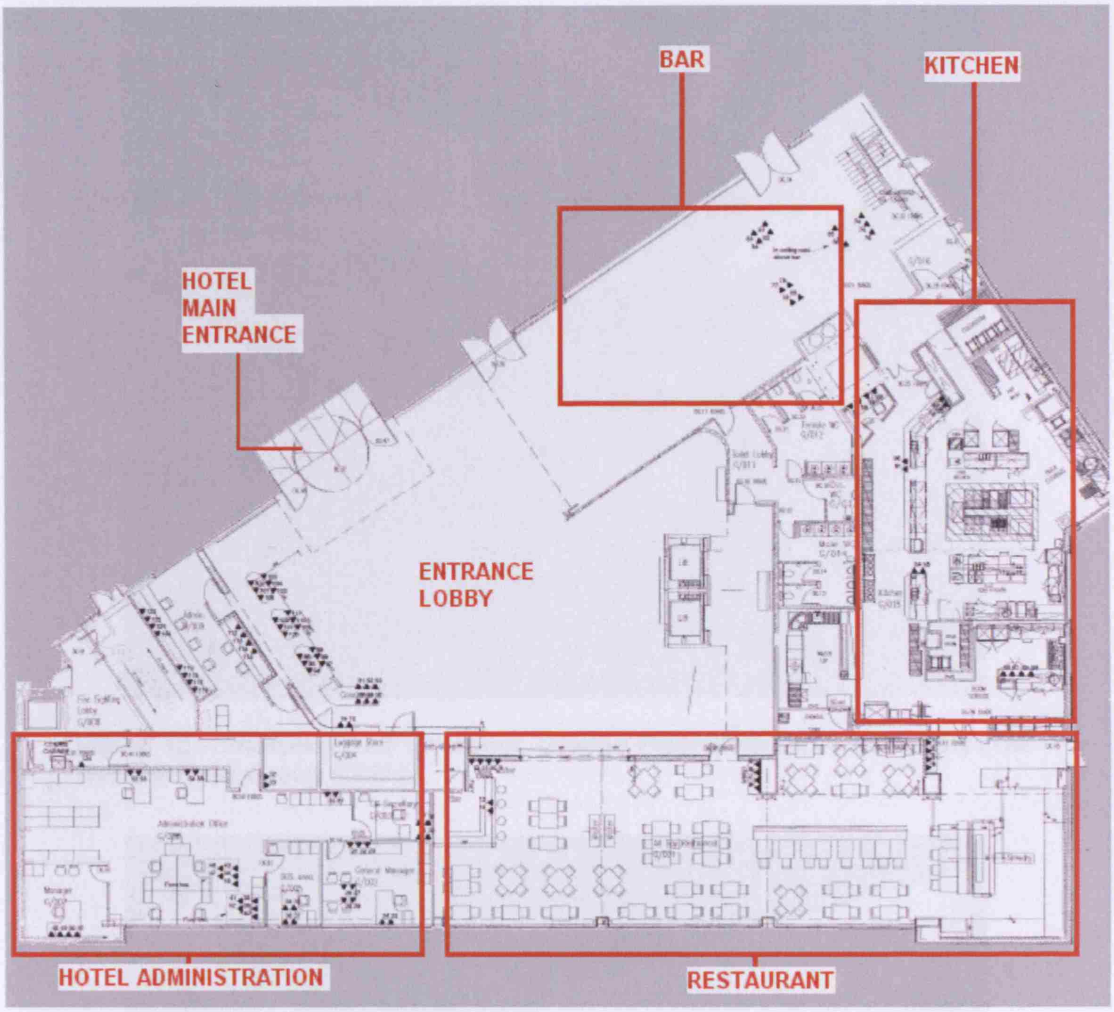

Figure 12 – Ground Floor Layout, Radisson SAS Liverpool

Figure 12 shows the ground floor layout. This level is home to the main entrance lobby to the hotel (Figure 13), a bar (Figure 14) and a separate restaurant (Figure 15). The kitchen and main administration offices are also located here. Access to upper levels from the ground floor is provided by a pair of passenger lifts which run up the central spine of the main atrium, as shown in Figure 16.

Figure 13 – Radisson SAS Liverpool, Ground Floor Main Entrance Lobby (The Rezidor Hotel Group 2008b)

Figure 14 – Radisson SAS Liverpool, Bar (The Rezidor Hotel Group 2008b)

Figure 15 – Radisson SAS Liverpool, Ground Floor Restaurant Interior View (The Rezidor Hotel Group 2008b)

Figure 16 – Radisson SAS Liverpool, Central Atrium, View from Ground Floor Showing Central Passenger Lift Core (The Rezidor Hotel Group 2008b)

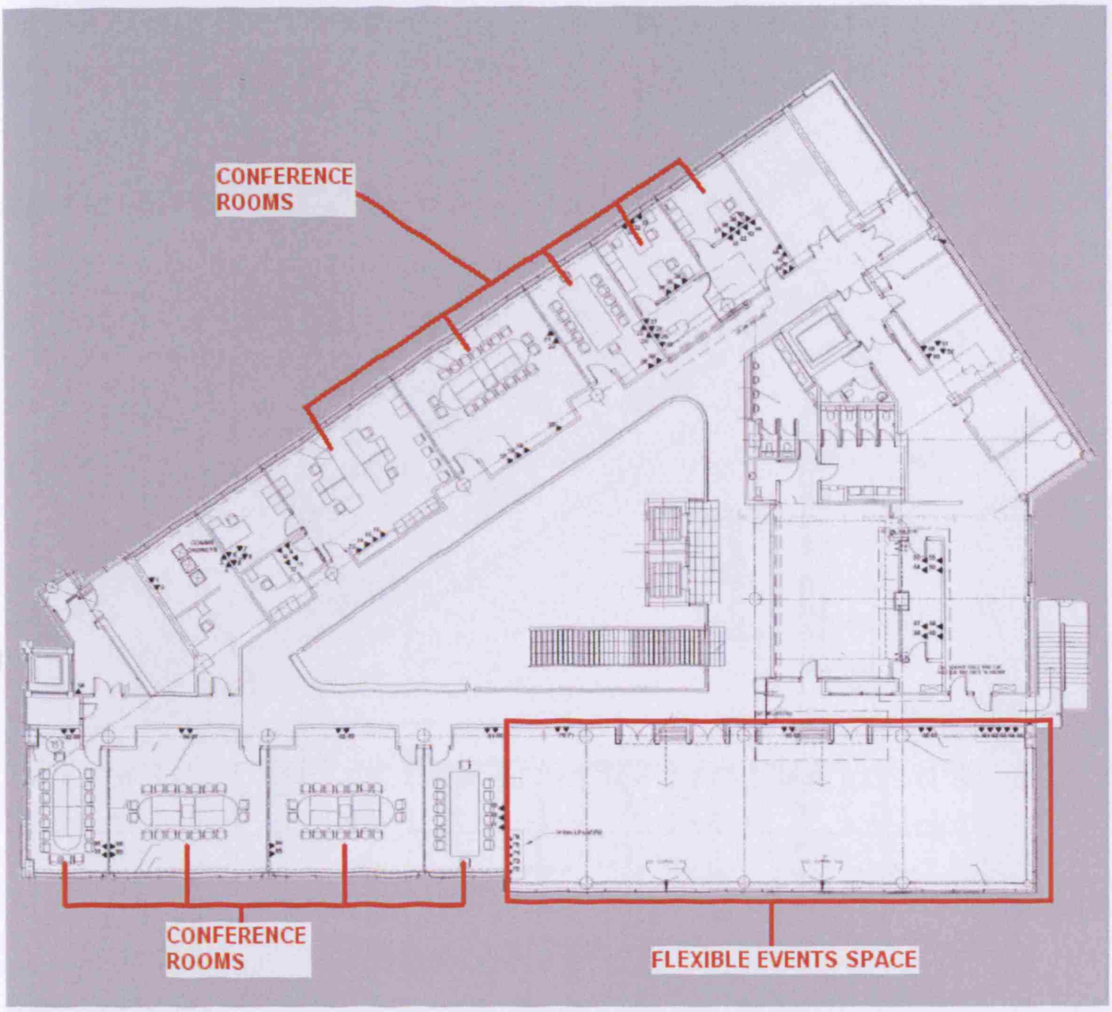

Figure 17 – First Floor Layout, Radisson SAS Liverpool

The first floor level, shown in Figure 17, has 9 multi-purpose rooms suitable for holding meetings, workshops and conference activities. There is also a flexible events space suitable for gatherings of up to 180 people. This can be used for formal functions, performances, weddings, receptions and other such events.

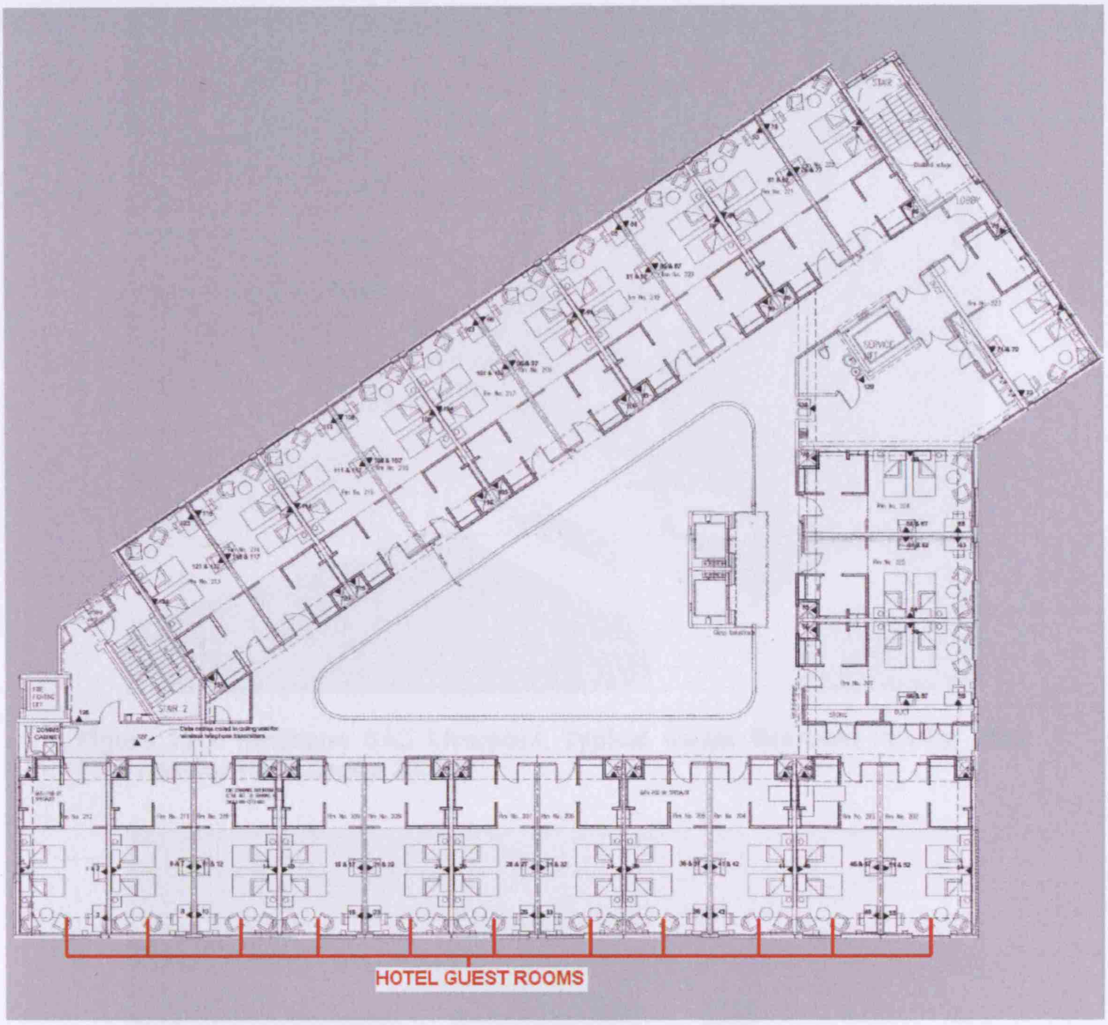

Figure 18 – Second to Ninth Floors, Typical Layout, Radisson SAS Liverpool

Floors 2 – 9 are largely identical, comprising hotel guest bedrooms as shown in Figure 18. In total there are 200 guest bedroom units, each with their own separate bath and shower. The rooms are provided with tea/coffee making facilities, hairdryers, electric clothes irons, mini-bars and television sets. Each room has its own independent climatic control provided by a four-pipe fan coil unit, the operation of which is explained in more detail in Section 5.4 (page 43). The rooms are decorated internally in a variety of styles, samples of which are shown in Figure 19 and Figure 20.

Figure 19 – Radisson SAS Liverpool, Typical Guest Bedroom Interior View (The Rezidor Hotel Group 2008b)

Figure 20 – Radisson SAS Liverpool, Large Guest Suite Interior View (The Rezidor Hotel Group 2008b)

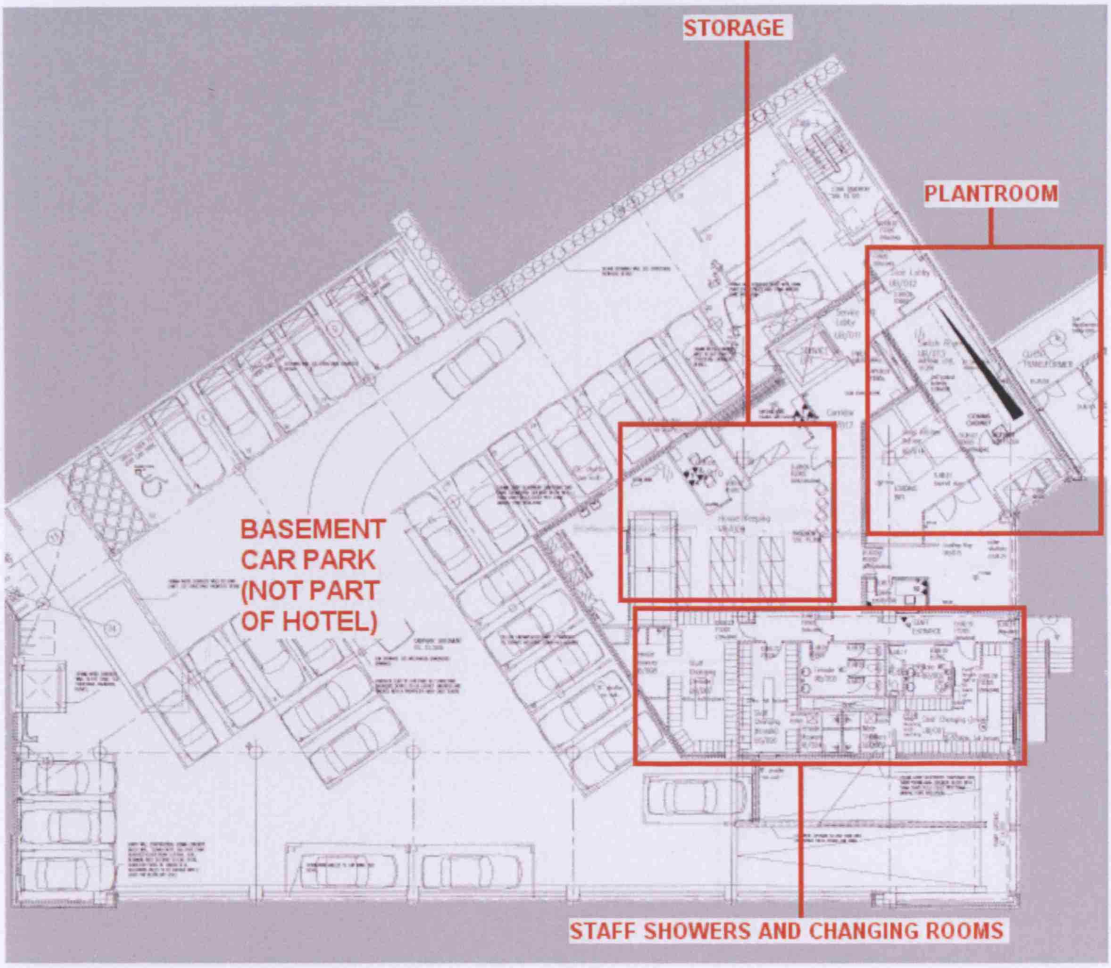

Figure 21 – Upper Basement Layout, Radisson SAS Liverpool

The upper basement layout is shown in Figure 21, comprising staff changing rooms, storage areas for housekeeping equipment and consumables, and electrical plant space. Details of the hotel's electrical installation are covered in Section 5.3 (page 41).

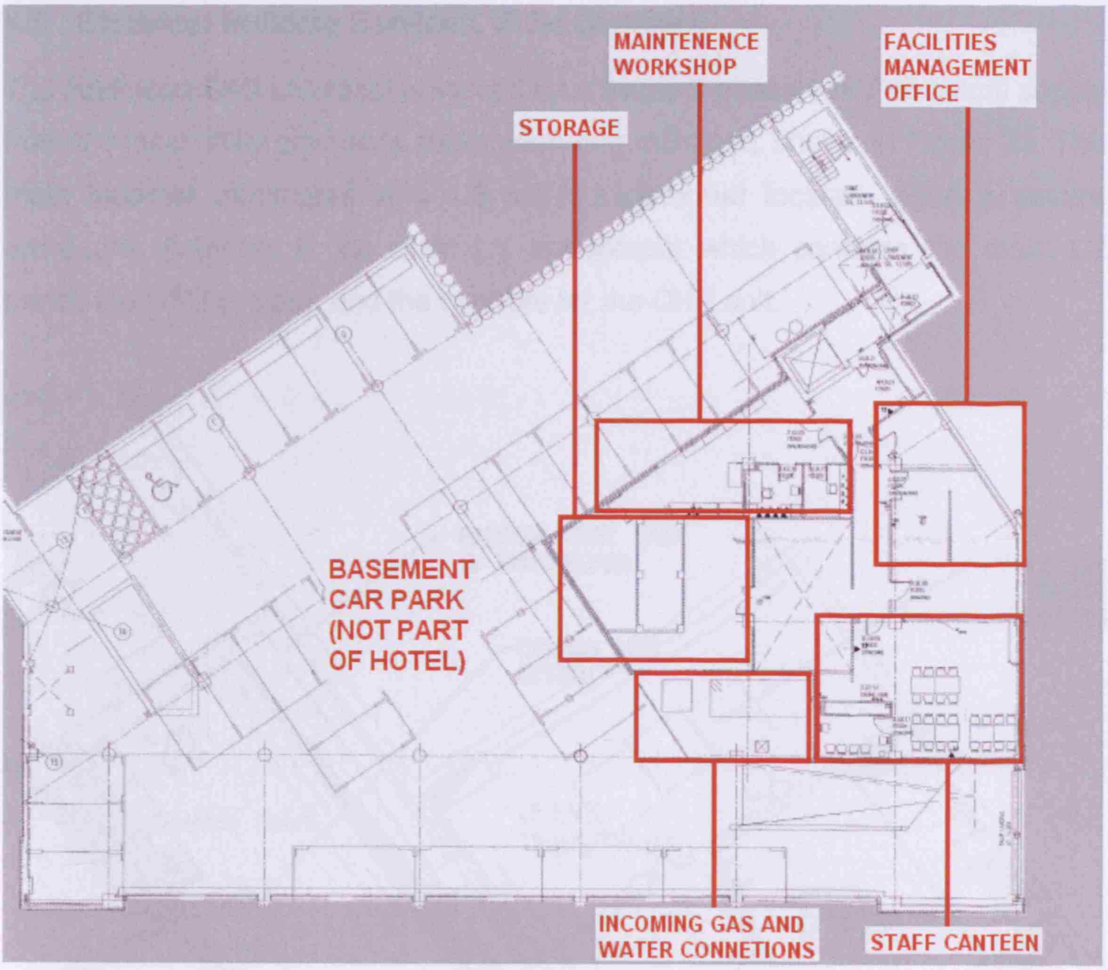

Figure 22 – Lower Basement Layout, Radisson SAS Liverpool

The lower basement level, shown in Figure 22, is home to the staff canteen, the maintenance workshop, storage space for engineering materials and spare parts, and the facilities management office. The incoming gas and water utility connections are also made within the lower basement. Further details of these, along with the building's mechanical services, are given in Section 5.4 (page 43).

5.3 Electrical Building Services, Brief Overview

The Radisson SAS Liverpool is served by a single 3-phase 11kV electrical supply from the local utility provider's sub-station ring main unit, shown in Figure 23. The main incomer terminates in a 1.5 MVA transformer located within a secure enclosure. Adjacent is the main LV switchroom which contains the main LV panel, the UPS system, and the controls for the CHP unit.

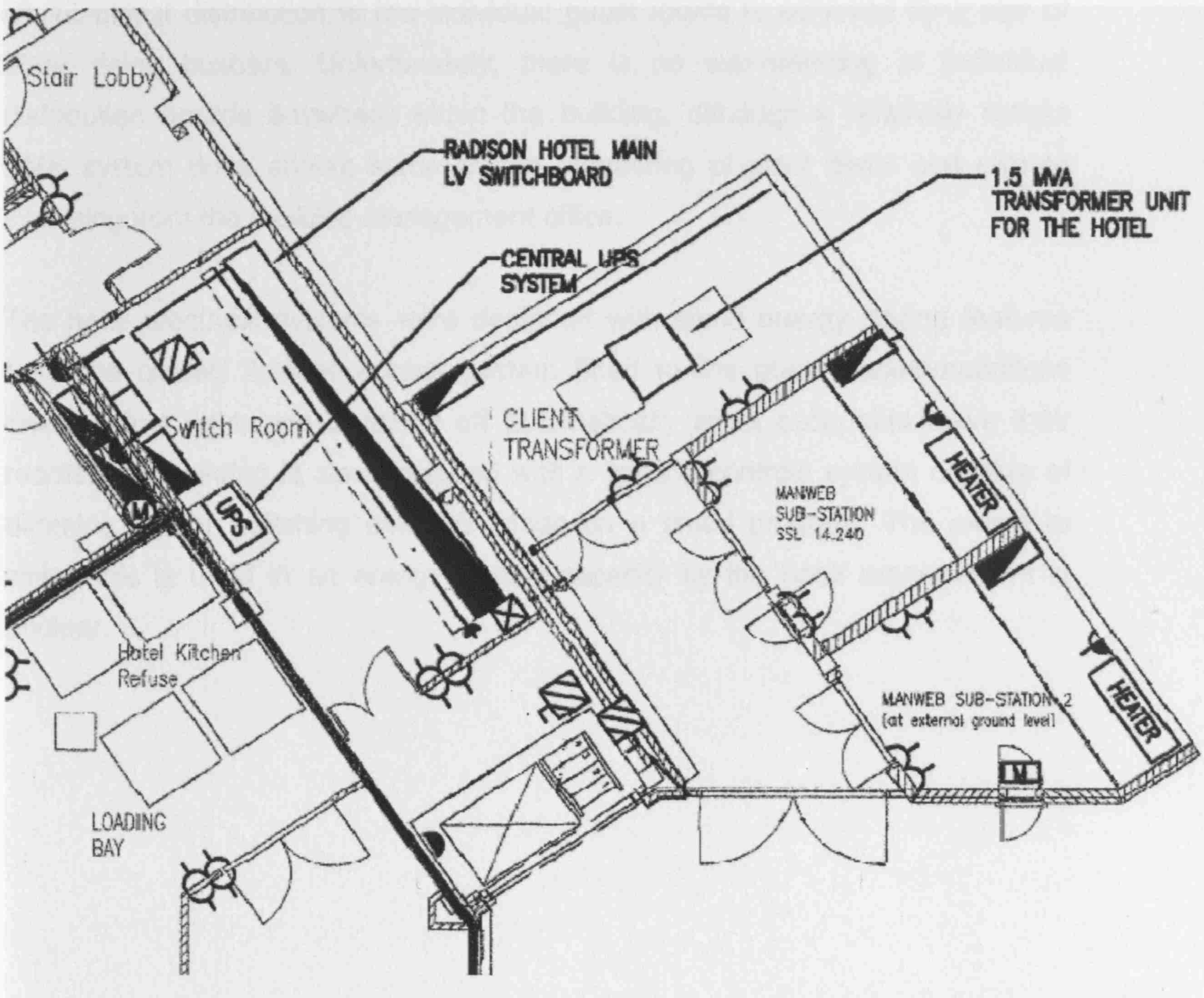

Figure 23 – Upper Basement Level, Incoming Electrical Supply Connection and Major Electrical Plant

The main LV switchboard is segregated into essential and non-essential sections, with critical items such as the security and fire alarm panels, and the fire fighting lift protected by the CHP unit, which is designed to be capable of operating as a stand-by generator. The 50 kVA UPS system supports those distribution boards serving the hotel administrative areas and the kitchen, preventing a sudden catastrophic loss of power to these areas in the event of a supply interruption.

The hotel is served by 2 passenger lifts, a service lift, and a dedicated fire fighting lift. Electrical distribution to the individual guest rooms is achieved by a pair of 630A rising busbars. Unfortunately, there is no sub-metering of individual distribution boards anywhere within the building, although a relatively simple BMS system does enable some limited monitoring of plant items and remote switching from the facilities management office.

The hotel electrical systems were designed with some energy saving features from the outset. A door access system fitted to the guest accommodations ensures that lights are switched off automatically when occupants leave their rooms. The building is also equipped with a lighting controls system capable of dimming and/or switching different zones on a timed program. The extent to which this is used in an energy saving capacity by the hotel management is unclear.

5.4 Mechanical Building Services, Brief Overview

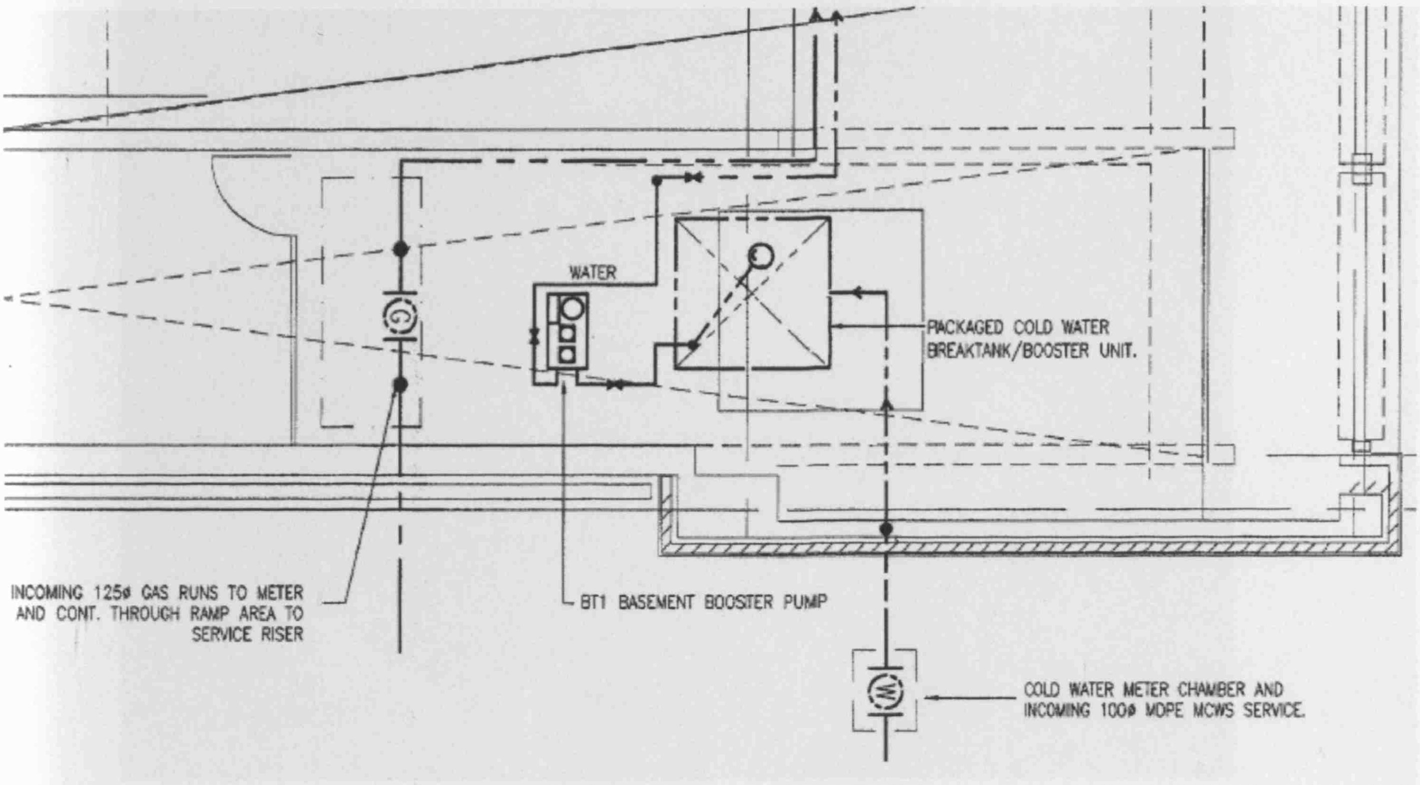

Figure 24 – Lower Basement Level, Gas and Water Utility Connections

The incoming gas service enters the building below ground level, terminating in a gas meter housing in the lower basement as shown in Figure 24. From here it feeds the first floor kitchen, the second floor food preparation area, the CHP unit, and the boilers. The mains cold water supply also enters the building at lower basement level (also shown in Figure 24), terminating in a storage break tank. From this point, a twin booster pump set supplies water to the 27,000 litre main cold water storage tank sited at roof level. Both the gas and water supply connections are metered at the point of entry.

Figure 25 – Radisson SAS Liverpool, Packaged Gas Fired Boiler Plant

The primary boiler plant consists of three gas fired packaged boilers, as shown in Figure 25. The circulation pumps supply low temperature hot water at a nominal 76°C (although this is adjustable via the BMS) from the boilers to air handling units, fan coil units etc.

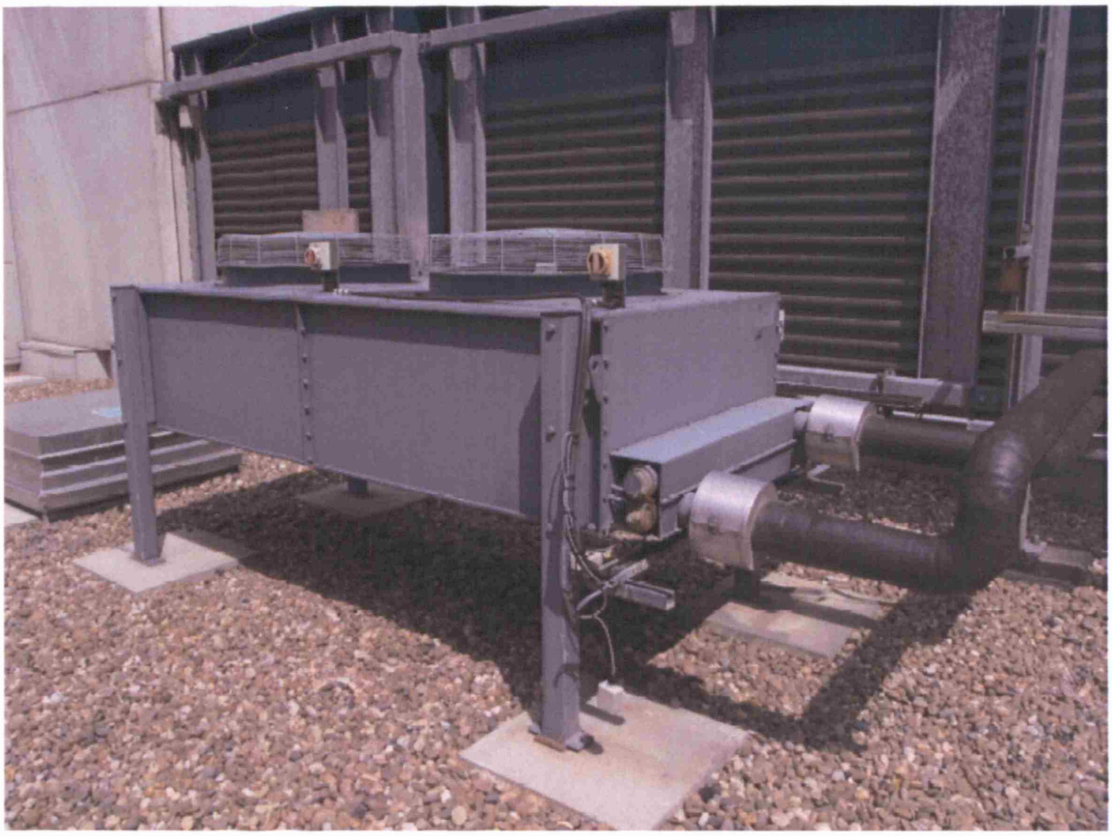

Figure 26 – Radisson SAS Liverpool, Air-Cooled Chiller, Roof Level

The cooling plant comprises 2 no. packaged air-cooled liquid chillers, located at roof level, each rated at 75% of the design load (see Figure 26). The units generate chilled water at 7℃ flow and 12℃ return, which is pumped to the building's air handling units and fan coil units.

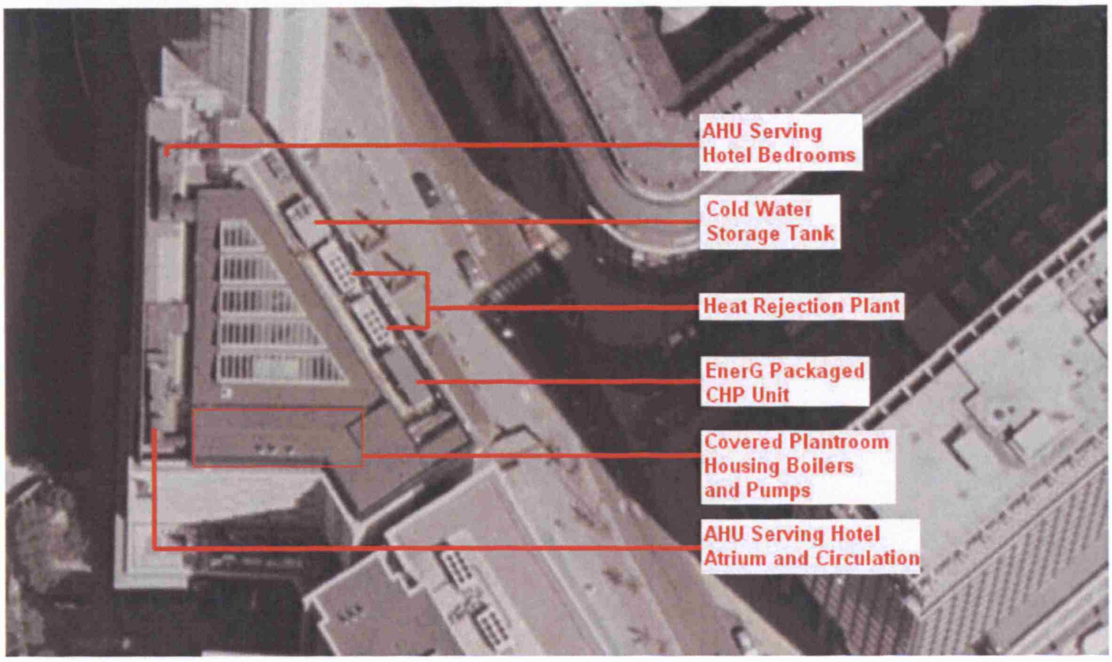

Figure 27 – Satellite Image, Radisson SAS Liverpool, Location of Major Roof Plant Items (Google Maps 2008b)

The aforementioned boilers and chillers, along with the majority of the other mechanical plant items are found at roof level, as illustrated in Figure 27. Figure 27 also shows 2 of the 6 no. air handling units which provide the supply and extract of fresh air to the hotel. The supply air temperature is nominally 14°C (adjustable via the BMS) and the units incorporate heat recovery using run around type coils. Toilets and staff changing room areas are served by dedicated extract fans exhausting at roof level.

Hotel bedrooms are served by four-pipe fan coil units (FCUs), which also supply under-floor heating circuits to the guest bathrooms. The door access system detects when occupants are present and determines the operating mode for the fan coil units. When no guests are present, the FCUs operate to a wide tolerance band with a set point of 17°C. When guests are present, the fan coils aim to keep the room temperature to a tight band around 21°C, and the under-floor heating circuit to the bathrooms is enabled. Guests are able to control the fan speed and change the FCU temperature set point by +/- 2°C.

5.5 Combined Heat and Power Plant (CHP)

Figure 28 – Radisson SAS Liverpool, EnerG Packaged CHP Plant, Roof Level

The hotel's CHP scheme consists of an EnerG 206 unit mounted at roof level within an acoustic enclosure, as shown in Figure 28. The unit is a naturally aspirated spark-ignition reciprocating engine running on natural gas, with a nominal electrical output of 206 kWe, and a corresponding nominal heat output of 324 kWt (Appendix 12.24, page 163). The unit has been certified by Defra[14] and issued with a Combined Heat and Power Quality Assurance (CHPQA) programme certificate (Appendix 12.29, page 168). The CHPQA certificate confirms that the unit's electrical efficiency is 31% and its heat production efficiency is 48.08%.

[14] Defra, the UK Department for Environment, Food and Rural Affairs, www.defra.gov.uk

The CHP unit is owned and maintained by EnerG, supplying heat and power to the hotel under a 10 year contract running to February 2014. The Radisson SAS uses the CHP scheme to meet part of their electrical load, aiming to run the unit 24 hours a day for around 720 hours a month. Scheduled monthly downtime for maintenance and repairs is of the order of 10 hours per month. The actual monthly running hours achieved are discussed in more detail in Section 7.1 (page 61).

The hotel pays EnerG for electricity generated from the CHP plant at a constant price of 2p/kWh, rather than paying grid electricity rates of 6.98p – 9.35p per kWh during the day and 3.84p – 4.56p per kWh during the night (defined as midnight to 7am). It also uses the 'free' thermal output from the unit to help supply their high heating and hot water demands. When the unit is not in operation, the hotel purchases all of its electricity from the grid at night time electricity rates and uses its conventional boiler plant for heating as required.

The CHP plant requires regular maintenance and is fitted with a remote monitoring and control system that offers 2-way communication between the unit and EnerG. The unit does not modulate its output and is sized so that it never produces more electricity or heat than the hotel can use. As a result, there are no export arrangements for supplying electricity to the grid or neighbouring buildings and neither is there any heat rejection plant.

6 HOTEL ENERGY AND CARBON ANALYSIS

The environmental performance of the Radisson SAS Liverpool was established by carrying out a comprehensive energy, carbon and cost analysis of the building's utility consumption, as detailed in this part of the report. This analysis enables the case study hotel to be benchmarked against other similar buildings (Section 10, page 77), and allows the contribution of the building's small-scale CHP unit to be placed in context (Section 7, page 60).

6.1 Methodology

A set of complete utility bills for the case study hotel were obtained for the period January – December 2007, covering all metered water, gas and electricity (Appendix 12.1, page 105). As mentioned in Section 5.3 (page 41), no arrangements for sub-metering energy or water use are in place at the hotel, so only bulk consumption information was available.

A number of different performance metrics were calculated in order to benchmark the case study hotel against other buildings. These included values on a per square meter basis, on a per room basis, and on a per guest-night basis.

Determining performance on a per m2 basis and on a per room basis was relatively simple. The hotel's own records show that the conditioned internal floor area is 11,526 m2, with 194 guest rooms. Three of these guest rooms are actually 'suites' made up of 3 rooms each with connecting doors, so for all intents and purposes there can be said to be 200 rooms.

Determining the number of guest-nights proved to be a more complex undertaking. A 'guest-night' is a common metric used in the hotel industry and represents one guest being checked in for one night. No data was obtained from the hotel accounts system on exact guest numbers during the case study period. To enable energy consumption and emissions to be evaluated on a per guest-night basis, the number of guest-nights was calculated using assumptions as detailed in Appendix 12.2 (page 107).

6.2 Water Consumption

From the metered utility consumption data found in Appendix 12.1 (page 105) it can be seen that in 2007 the hotel consumed 19,388 m3 of water, averaging at just over 1616 m3 a month. The calculations detailed in Appendix 12.3 (page 109) show that this equates to 266 litres/room/day or 203 litres/guest-night.

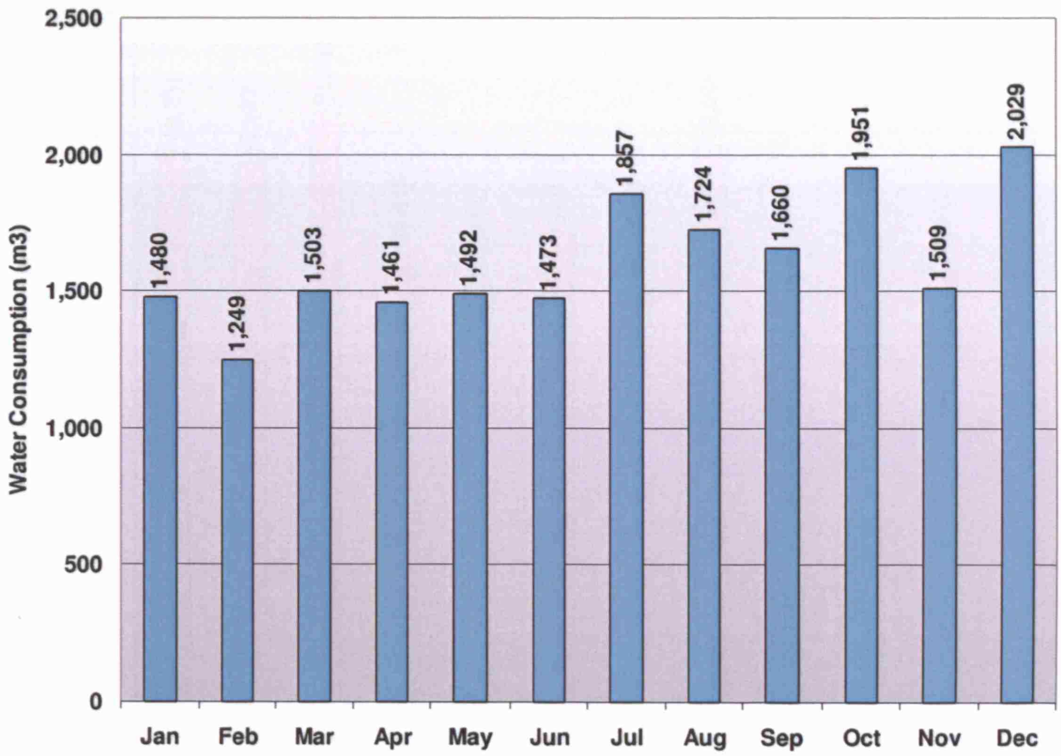

Figure 29 – Breakdown of Annual Monthly Water Consumption, 2007

Figure 29 shows the annual monthly variation in mains cold water consumption. It can be seen that the variation in consumption does not appear to follow any pattern that could be attributed to seasonal weather cycles i.e. summer, winter, mid-season. It is more likely that water consumption is instead directly linked to the number of guests present at the hotel at any given time.

6.3 Gas Consumption

Appendix 12.1 (page 105) shows that during 2007 the hotel consumed 515,366 m3 of natural gas, averaging nearly 43,000 m3 a month. The calculations in Appendix 12.4 (page 110) can be used to express the gas consumption of the hotel as 494 kWh/m2 or 60 kWh/guest-night.

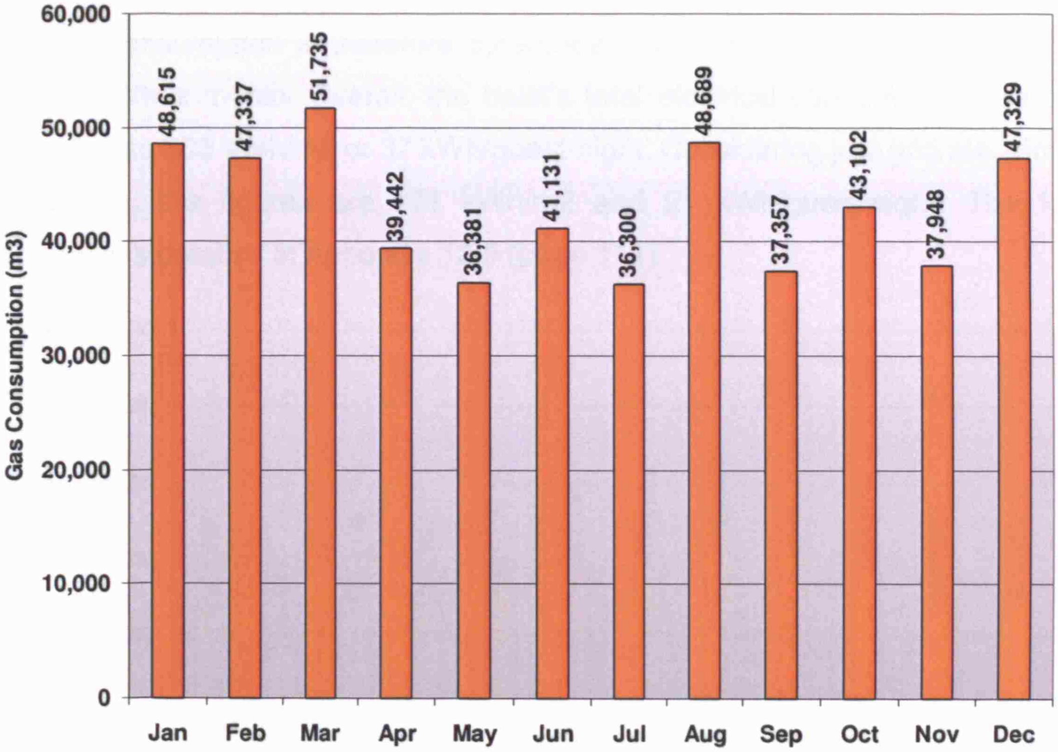

Figure 30 – Breakdown of Annual Monthly Gas Consumption, 2007

Natural gas is used to meet space heating and hot water demand at the hotel, with the exact monthly consumption breakdown as shown in Figure 30. Annual variation in gas consumption can be seen to follow a seasonal pattern, generally rising in winter and falling in summer. There is a spike in consumption during August that does not follow this trend. Without sub-metered data apportioning gas usage to space heating and hot water it is difficult to comment on the reason for this sudden rise.

6.4 Electricity Consumption

It can be seen from the metered consumption data contained within Appendix 12.1 (page 105) that in 2007 the hotel consumed 1,968,064 kWh of grid supplied electricity, with an additional 1,522,505 kWh of electricity supplied from the on site CHP unit. As the CHP unit has no import/export arrangement with the local grid, all of the electricity generated must be consumed by the building. Total electrical consumption is therefore 3,490,569 kWh annually, averaging around 291,000 kWh a month. Overall, the hotel's total electrical consumption can be expressed as 303 kWh/m2 or 37 kWh/guest-night. Considering just grid electricity on its own, the figures are 171 kWh/m2 and 21 kWh/guest-night. The full calculation is detailed in Appendix 12.5 (page 111).

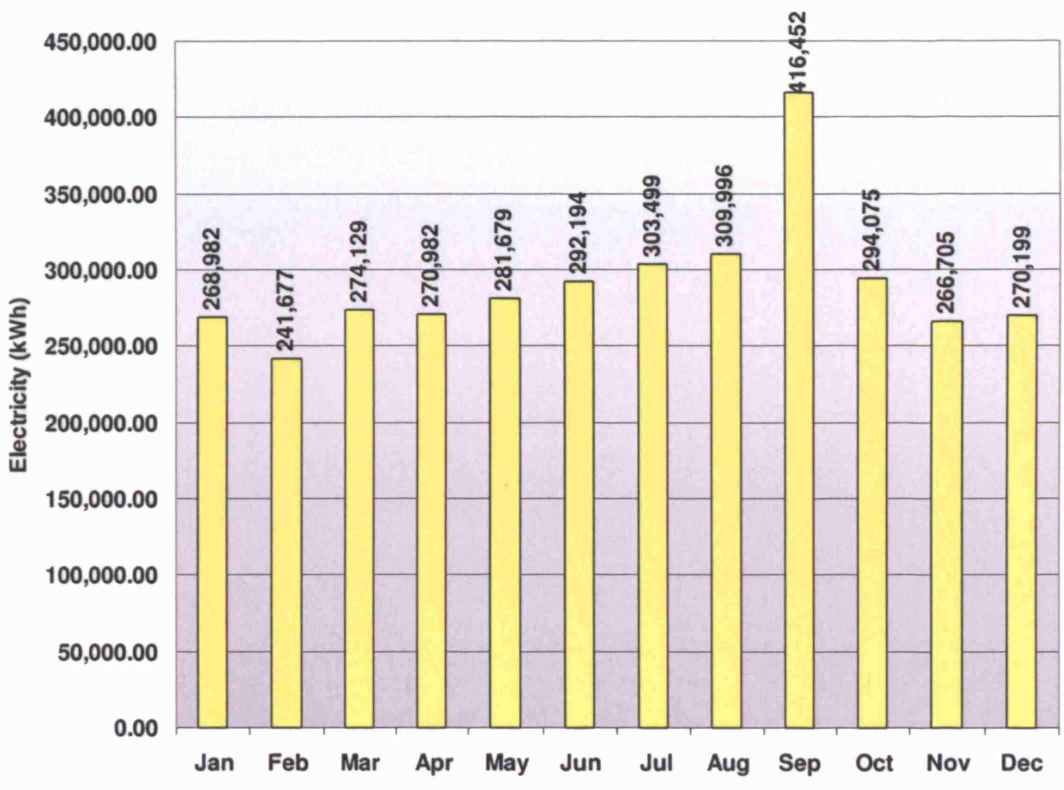

Figure 31 – Breakdown of Annual Monthly Electrical Demand, Grid and CHP Produced Electricity, 2007

Figure 31 shows the actual annual monthly variation in electricity consumption during 2007. The consumption pattern appears to follow a bell curve distribution, with an increase in electricity use during summer months. This is likely linked to increased cooling demand due to higher ambient temperatures during this period. There are also spikes in consumption during January and September. Without any sub-metered information on power consumption however, it would be inappropriate to speculate on the cause of these increases.

6.5 Heat Demand

Heat demand at the hotel is unmetered, and was instead estimated based on a number of assumptions relating to the thermal conversion efficiency of the heating plant and the gas consumption of various systems. These assumptions, along with the calculation methodology, are explained in Appendix 12.6 (page 112). The annual heating energy requirements of the hotel for 2007 were calculated as 2,898,061 kWh, expressed alternatively as 251 kWh/m2 or 30 kWh/guest-night.

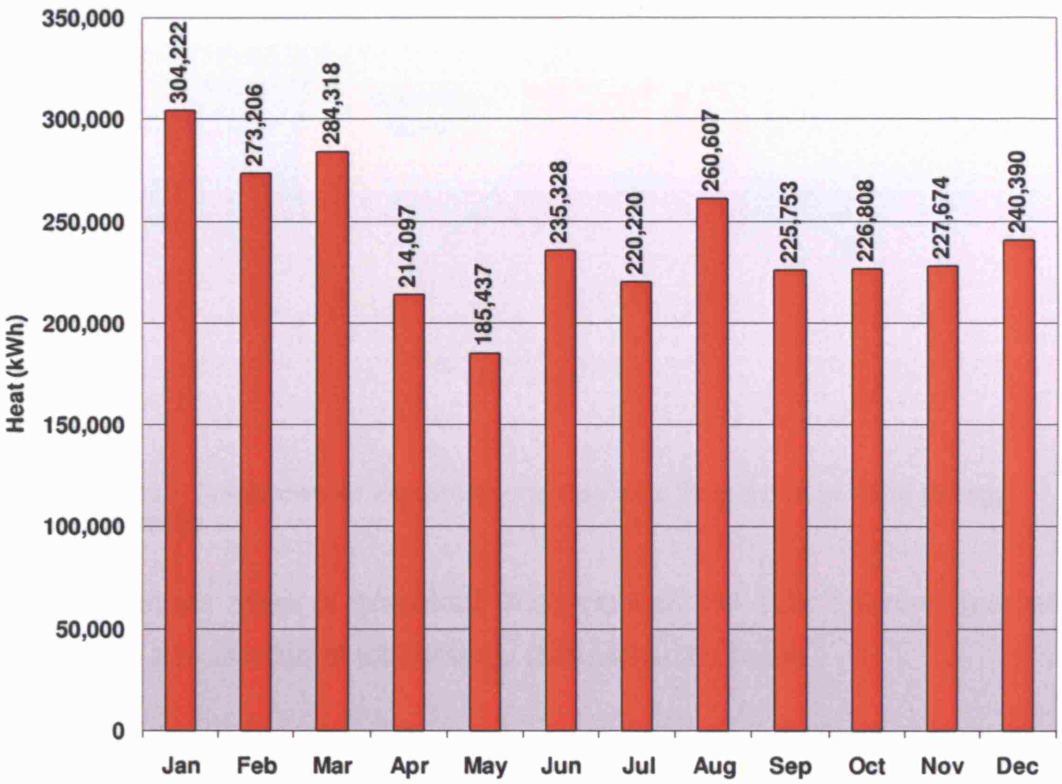

Figure 32 – Breakdown of Annual Heat Demand, 2007

Figure 32 shows the calculated annual monthly variation in heat demand for the hotel, which is broadly similar to the gas consumption profile.

6.6 Total Energy Use Intensity

'Energy Use Intensity' (EUI) is a common benchmark used in the post-occupancy evaluation of hotel buildings. It combines the consumption figures for gas and electricity into a single energy unit. The calculation in Appendix 12.7 (page 115) shows that the Energy Use Intensity of the hotel can be expressed as either 797 kWh/m2 or 97 kWh/guest-night.

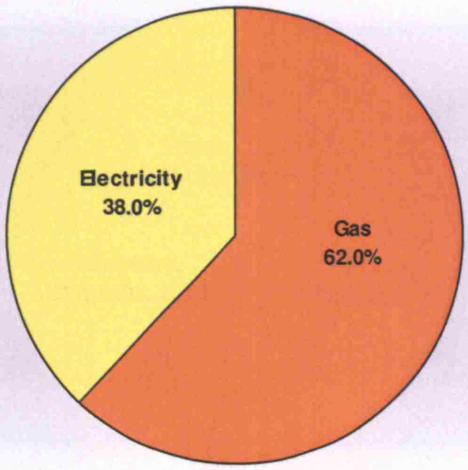

Figure 33 – Breakdown of Electricity and Gas as a Proportion of Total Energy Use Intensity

Figure 33 above gives a graphical illustration of the split between gas and electricity as a proportion of total energy demand at the hotel.

6.7 Total Carbon Footprint

The carbon emissions generated by the case study hotel were calculated on both a 'per m2' and a 'per guest-night' basis by applying conversion factors to the energy and water consumption data. The full calculation is described in detail in Appendix 12.8 (page 116). The annual emissions from the hotel related to utility consumption during 2007 totalled just over 2.2 million tonnes of CO2, equivalent to 195 kgCO2/m2 annually, or 23 kgCO2/guest-night.

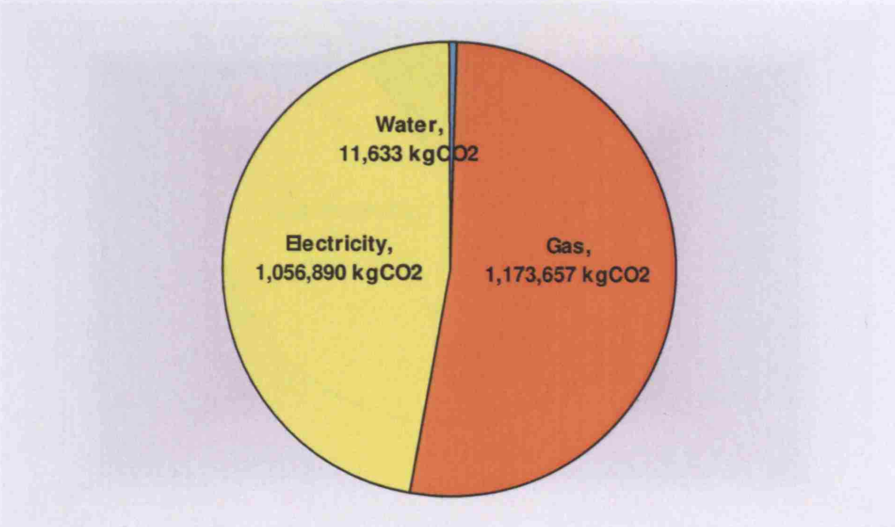

Figure 34 – Breakdown of Annual Utility-Related Carbon Emissions, Radisson SAS Liverpool, 2007

Figure 34 above shows the annual split between the carbon emissions generated by the hotel's electricity, water, and gas consumption.

6.8 Total Utility Costs

Utility per-unit pricing data was obtained from the hotel records and used to calculate a breakdown of annual utility costs. The full calculation is elaborated on in Appendix 12.9 (page 118). The total annual expenditure of the hotel on utilities was £316,809. This reduces to £293,194 if mains water is excluded.

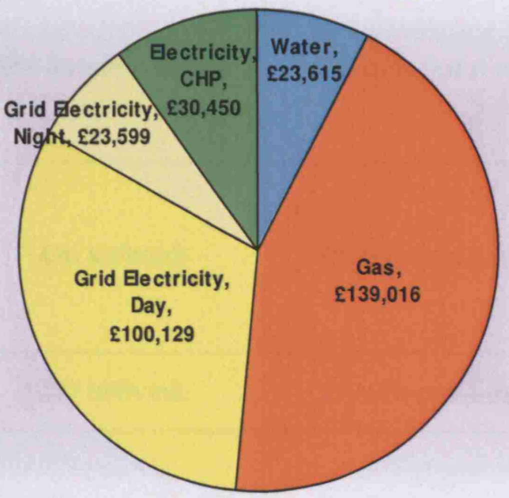

Figure 35 – Annual Breakdown in Utility Costs, Radisson SAS Liverpool, 2007

The cost breakdown between gas, water and grid electricity is as shown in Figure 35. The annual total utility costs for the hotel can be expressed as £27.49/m2 or £3.32/guest-night. If water costs are excluded and the focus is purely on gas and grid electricity, then the figures become £25.44/m2 or £3.07/guest-night.

6.9 Performance Summary

Table 1 summarises the calculated performance metrics and compares them against a number of benchmark figures.

	Per Room/m2 Performance	Per Guest-Night Performance	Comparison Benchmarks
Water	**266 litres/room/day**	203 litres/guest-night	Scandic Hotels, Published Figures, **177 litres/room/day** (Bohdanowicz & Martinac 2007)
Gas	**494 kWh/m2**	60 kWh/guest-night	Luxury Hotel, Good Performance, **300 kWh/m2** (The Carbon Trust 1999)
Grid Electricity	171 kWh/m2	21 kWh/guest-night	-
Total Electricity	**303 kWh/m2**	37 kWh/guest-night	Luxury Hotel, Good Performance, **90 kWh/m2** (The Carbon Trust 1999)
Heat	251 kWh/m2	30 kWh/guest-night	-
Total Energy Use Intensity (EUI)	**797 kWh/m2**	97 kWh/guest-night	Nordic Swan Eco-Label, Class A Hotel, 2006, **420 kWh/m2** (Bohdanowicz & Martinac 2007)
Total Carbon Emissions	**195 kgCO2/m2**	23 kgCO2/guest-night	Typical UK Hotel **160 kgCO2/m2** (The Carbon Trust 1999)
Total Cost (inc. Water)	£27.49/m2	£3.32/guest-night	-
Total Cost (excl. Water)	£25.44/m2	£3.07/guest-night	-

Table 1 – Summary of Performance Metrics for Case Study Hotel, 2007

7 CONTRIBUTION OF CHP UNIT TO HOTEL PERFORMANCE

The small-scale CHP unit installed at the Radisson SAS Liverpool is the only low and zero-carbon technology system in the building. Assessing its contribution to reducing energy demand and emissions is therefore important when considering the overall environmental performance of the hotel. This can be achieved by calculating various performance metrics for a theoretical building, identical to the case study hotel, but without the CHP unit, and determining the difference between the two cases.

7.1 Contribution of CHP Unit to Meeting Electrical Demand

It can be seen from the measured data summarised in Appendix 12.1 (page 105) that the CHP unit produced 1,522,505 kWh of electricity during 2007, out of a total annual consumption figure of 3,490,569 kWh. This means that the unit is currently meeting 44% of the total annual demand for electricity as illustrated in Figure 36.

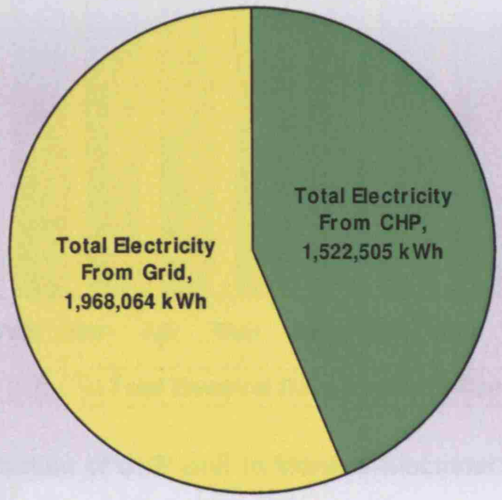

Figure 36 – Annual Total Electricity Production from Onsite CHP Plant as a Proportion of Total Electricity Requirements for Case Study Hotel, 2007

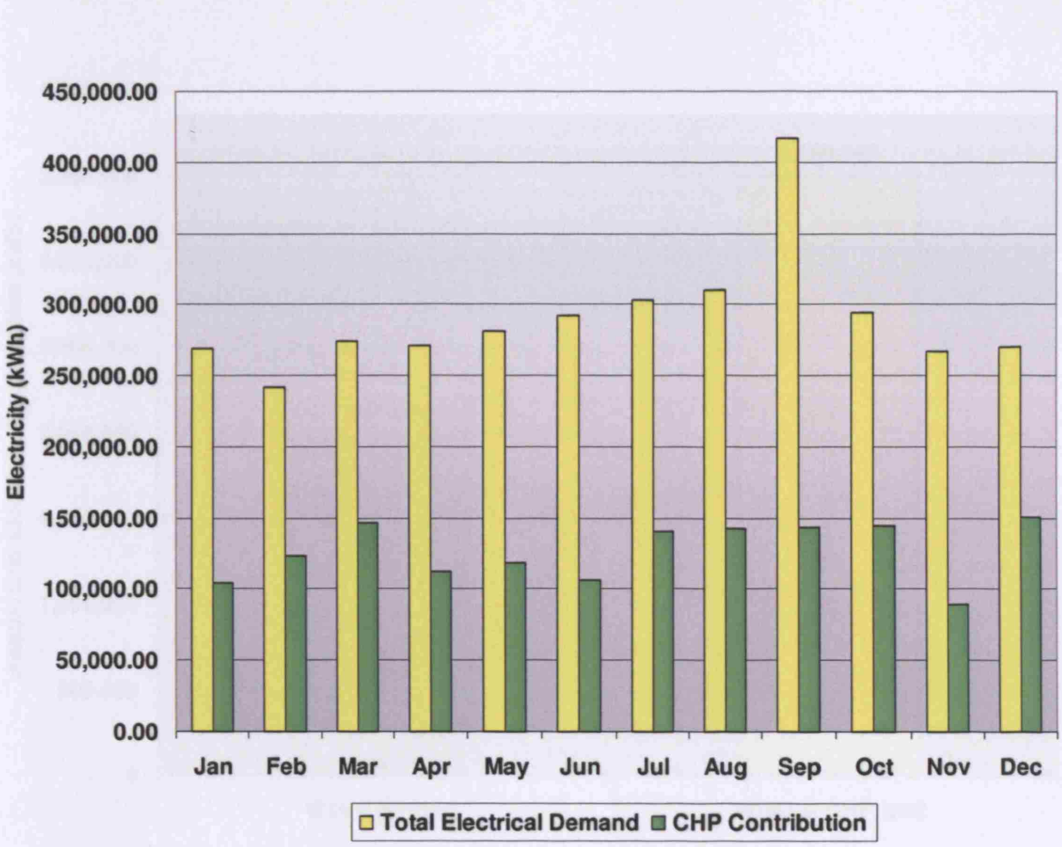

Figure 37 – Contribution of CHP Unit to Monthly Electrical Demand, Radisson SAS Liverpool, 2007

The monthly variation in CHP electricity production is as illustrated in Figure 37. It can be seen that there are some significant monthly variations in power output from the CHP unit. This should not occur, as the unit is intended to operate on 24-hour cycles for a target of 720 hours/month, as described previously in Section 5.5 (page 47). This corresponds to a target monthly output of 148,320 kWh/month, which was achieved in only 6 out of the 12 months of 2007.

This drop in CHP electricity production appears to be as a result of unscheduled downtime. How well the unit would perform if it was performing more reliably and only shut down during scheduled hours is discussed further in Section 8.1 (page 72).

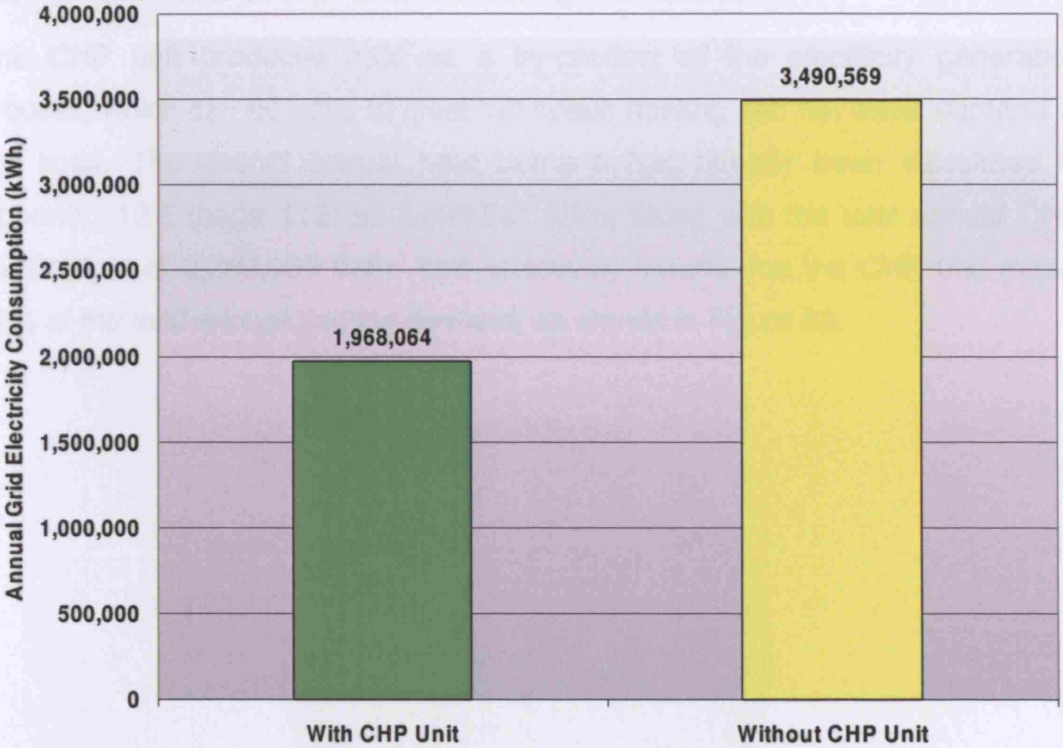

Figure 38 – Comparison of Grid Electricity Consumption of Case Study Hotel with and Without Small-scale CHP Unit Installation

Figure 38 compares the grid electricity consumption of the case study hotel, which has a CHP unit installed, with a theoretical, identical building, without a CHP unit. Appendix 12.10 (page 121) contains calculations confirming that the CHP unit reduces grid electrical consumption by 44% relative to the theoretical no-CHP case. This is relevant because the change in grid electricity consumption between the two cases is needed to assess the impact of the CHP unit on the building's carbon footprint and energy costs, discussed below in Section 7.4 (page 67) and Section 7.5 (page 69).

7.2 Contribution of CHP Unit to Meeting Heat Demand

The CHP unit produces heat as a by-product of the electricity generation process, which can be used to meet the space heating and hot water demand of the hotel. The overall annual heat demand has already been calculated in Appendix 12.6 (page 112) as 2,898,061 kWh, along with the total annual CHP heat output of 2,390,330 kWh. This effectively means that the CHP unit meets 82% of the total annual heating demand, as shown in Figure 39.

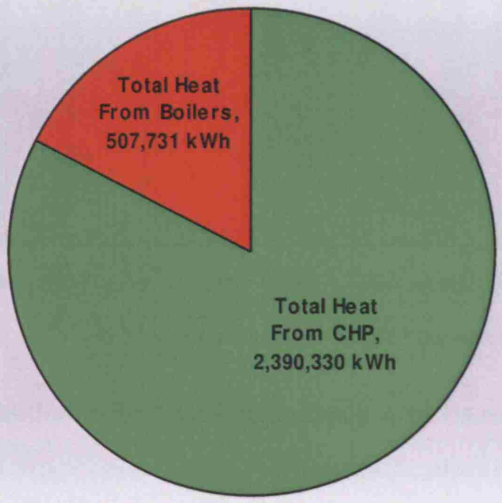

Figure 39 – Annual Total Heat Production from Onsite CHP Plant as a Proportion of Total Heating Requirements for Case Study Hotel, 2007

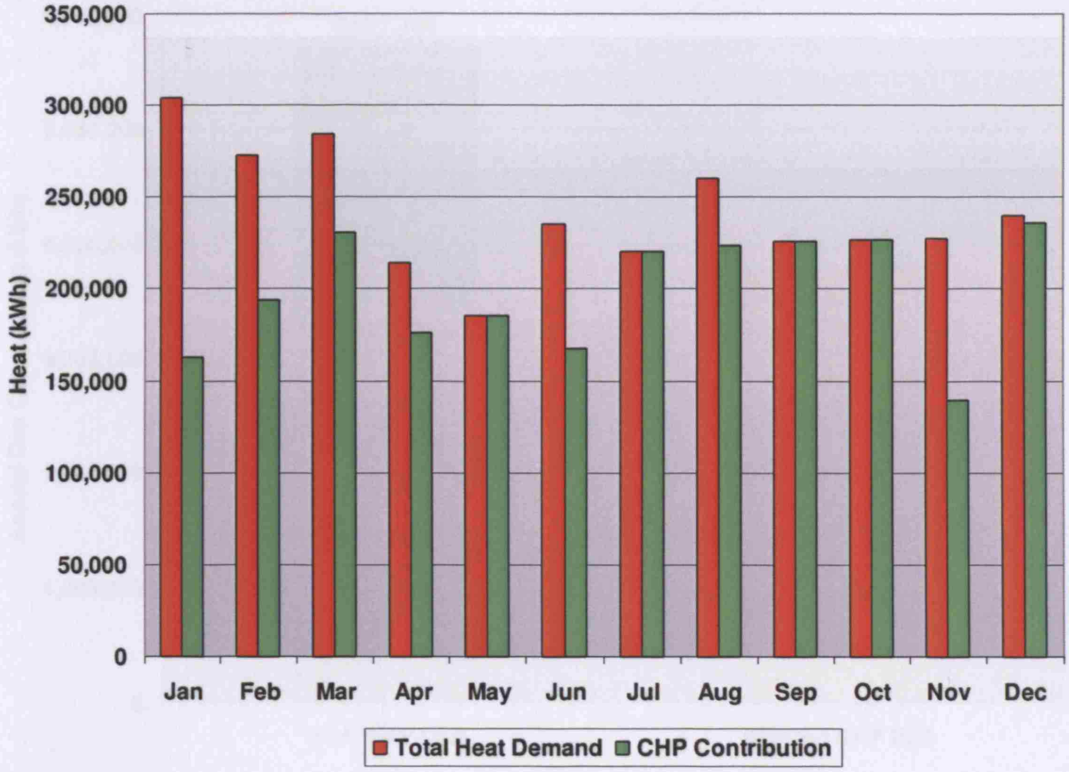

Figure 40 – Contribution of CHP Unit to Monthly Heat Demand, Radisson SAS Liverpool, 2007

The monthly variation in heat output is shown in Figure 40. As with the electrical output shown in Figure 37 (page 62), the monthly heat output changes depending on how often the plant is running to full capacity and how often it needs to be shut down for maintenance or repairs.

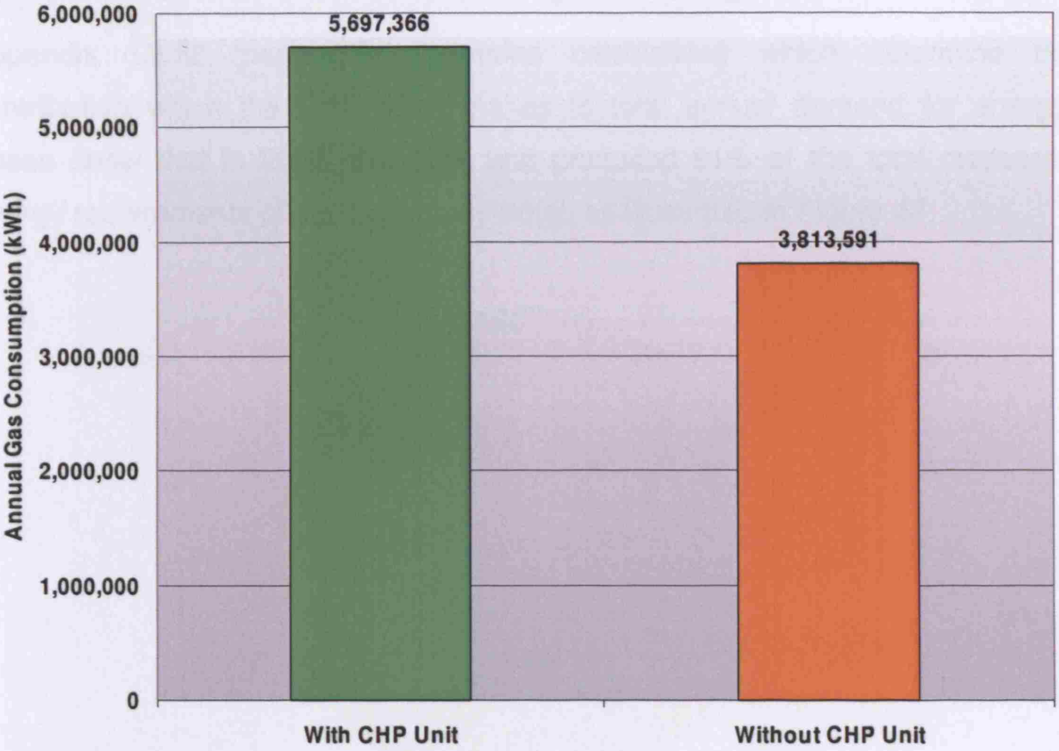

Figure 41 – Comparison of Natural Gas Consumption of Case Study Hotel with and Without Small-scale CHP Unit Installation

Figure 41 compares the natural gas consumption of the case study hotel, which has a CHP unit installed, with a theoretical, identical building, without a CHP unit. This is important because the difference in gas consumption between the two cases is needed to understand the impact of the CHP unit on the hotel's carbon footprint and energy costs, discussed below in Section 7.4 (page 67) and Section 7.5 (page 69).

If there was no CHP unit present in the building, then the gas previously used to generate electricity from the CHP plant would not be consumed at all. At the same time, all of the heating demand previously covered by the CHP unit would need to be met by the boilers instead. The calculations in Appendix 12.11 (page 122) show that an identical building to the case study hotel, without a CHP unit installed, would consume 33% less natural gas.

7.3 Contribution of CHP Unit to Meeting Total Energy Demand

Appendix 12.12 (page 124) contains calculations which determine the contribution which the CHP plant makes to total annual demand for energy. These show that in 2007, the CHP unit produced 61% of the total measured energy requirements of the case study hotel, as illustrated in Figure 42.

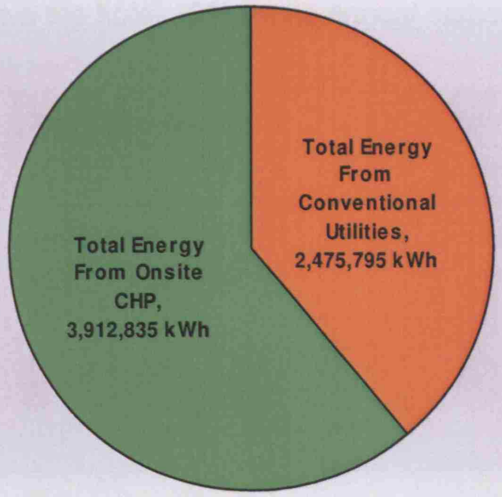

Figure 42 – Annual Total Energy Production from Onsite CHP Plant as a Proportion of Total Energy Requirements for Case Study Hotel, 2007

7.4 Contribution of CHP Unit to Reducing Carbon Footprint

Calculations in Appendix 12.13 (page 125) quantify the contribution which the CHP installation makes to reducing the hotel building's annual utility-related carbon emissions. Overall, an identical building to the case study hotel, without the CHP plant, would emit 2,671,738 kgCO2 per annum, versus 2,242,180 kgCO2 per annum for the base case, as shown in Figure 43. The CHP unit can therefore be said to save the hotel 16% on its annual carbon emissions.

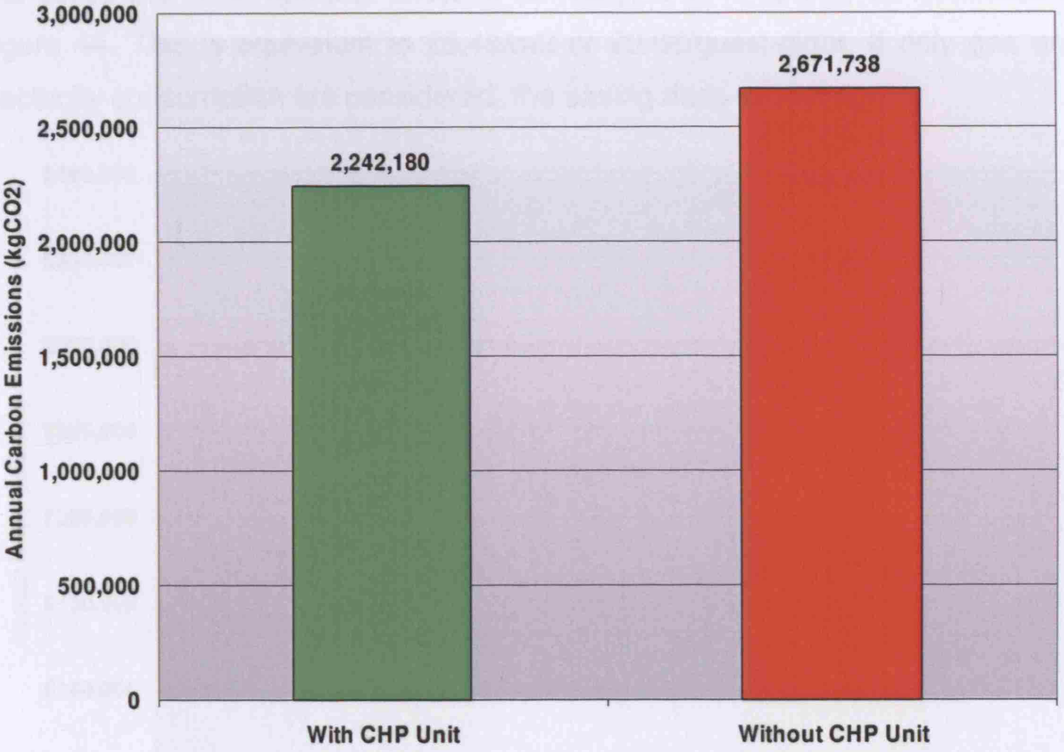

Figure 43 – Comparison of Carbon Dioxide Emissions of Case Study Hotel with and Without Small-scale CHP Unit Installation

The no-CHP case would have a carbon footprint equivalent to 232 kgCO2/m2, or 28 kgCO2/guest-night. The use of a CHP unit saves the hotel operator 429,558 kgCO2 annually, which can also be expressed as 37 kgCO2/m2 or 4.5 kgCO2/guest-night.

7.5 Contribution of CHP Unit to Reducing Energy Costs

The calculation in Appendix 12.14 (page 126) determines the cost of providing the same heat and power demand from a building identical to the case study hotel, but without a CHP unit installed. For the no-CHP case, the annual expenditure on utilities is £380,062 a year. The actual hotel building, with the CHP unit installed, has an annual utilities bill calculated in Appendix 12.9 (page 118) of £316,809. Therefore, in this case, it can be said that the use of a CHP unit saves the hotel operator £63,253 annually, a 17% saving, as illustrated in Figure 44. This is equivalent to £5.49/m2 or £0.66/guest-night. If only gas and electricity consumption are considered, the saving rises to 18.5%.

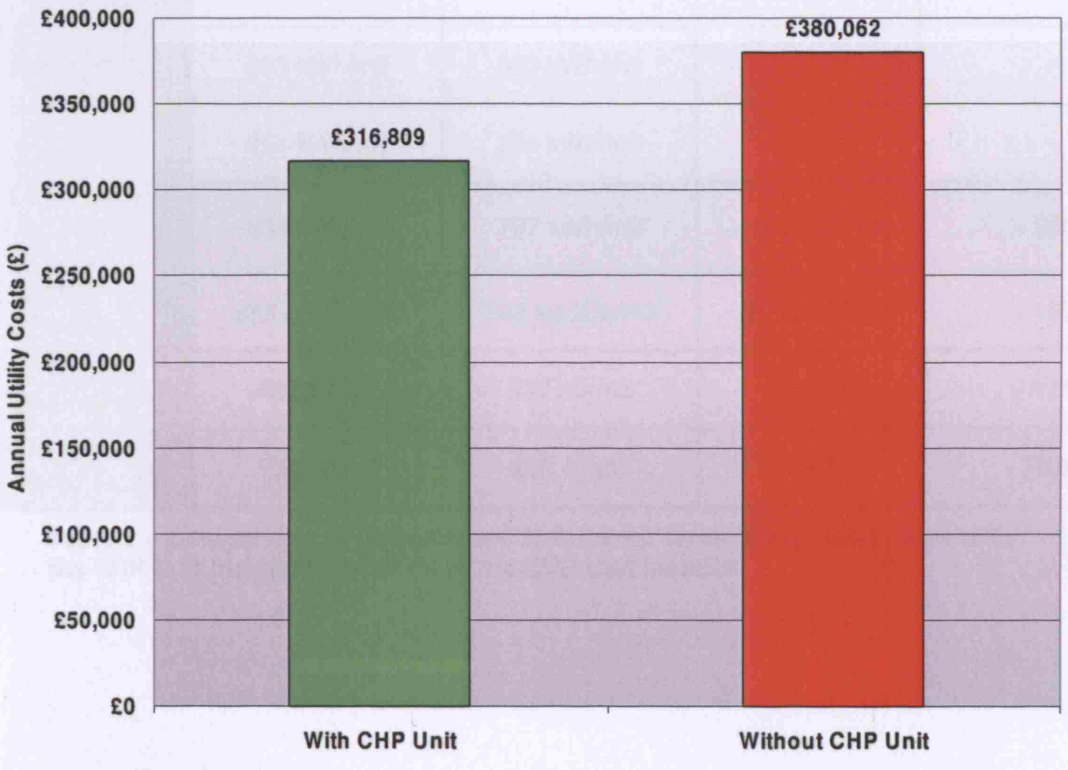

Figure 44 – Comparison of Annual Utility Costs of Case Study Hotel with and Without Small-scale CHP Unit Installation

7.6 Summary of Hotel Performance Metrics With / Without CHP Unit

The contribution of the CHP unit to the hotel's environmental performance is summarised below in Table 2. Overall, the use of a CHP unit delivers a 16% reduction in carbon emissions and an 18.5% saving in energy-related utility costs.

	Without CHP Unit	With CHP Unit	Change	% Change
Water	266 litres/room/day	266 litres/room/day	-	-
Gas	331 kWh/m2	494 kWh/m2	+ 163 kWh/m2	+ 49%
Grid Electricity	303 kWh/m2	171 kWh/m2	- 132 kWh/m2	- 44%
Total Electricity	303 kWh/m2	303 kWh/m2	-	-
Heat	251 kWh/m2	251 kWh/m2	-	-
Total Energy Use Intensity (EUI)	634 kWh/m2	797 kWh/m2	+ 163 kWh/m2	+ 26%
Total Carbon Emissions	232 kgCO2/m2	195 kgCO2/m2	- 37 kgCO2/m2	- 16%
Total Cost (inc. Water)	£32.97/m2	£27.49/m2	- £5.72	- 17%
Total Cost (excl. Water)	£30.93/m2	£25.44/m2	- £5.72	- 18.5%

Table 2 – Comparison of Performance Metrics for Case Study Hotel, Both with the CHP Unit Installed and Without the CHP Unit Installed

8 ALTERNATIVE SMALL-SCALE CHP ENERGY PROVISION SCENARIOS

As covered previously in Section 7 (page 60), the CHP plant is beneficial to the hotel operation from both an environmental and a financial perspective. This section of the report examines how the use of small-scale CHP plant can offer further carbon and cost savings. The Rezidor Hotel Group does not actually own the hotel property itself, and as such is unlikely to want to invest in upgrading the building fabric, especially as the hotel is only 4.5 years old at the time of writing. However, many of the building services systems, including the CHP unit, have a much shorter lifespan than the building materials themselves and may well be due a replacement or major overhaul within the next 5-10 years.

8.1 Scenario 1 – Improving Reliability of Existing EnerG 206 CHP Unit

As discussed in Section 7.1 (page 61), the existing EnerG 206 CHP unit (Appendix 12.24, page 163) is not performing optimally, being shut down regularly outside of scheduled hours. The calculation in Appendix 12.15 (page 128) considers what savings could be made if the unit performed to its target of 720 hours a month, with all maintenance occurring during scheduled hours. Improving reliability in this way is calculated to deliver a 1% reduction in carbon emissions, while having a minimal impact on utility costs (a 0.5% increase).

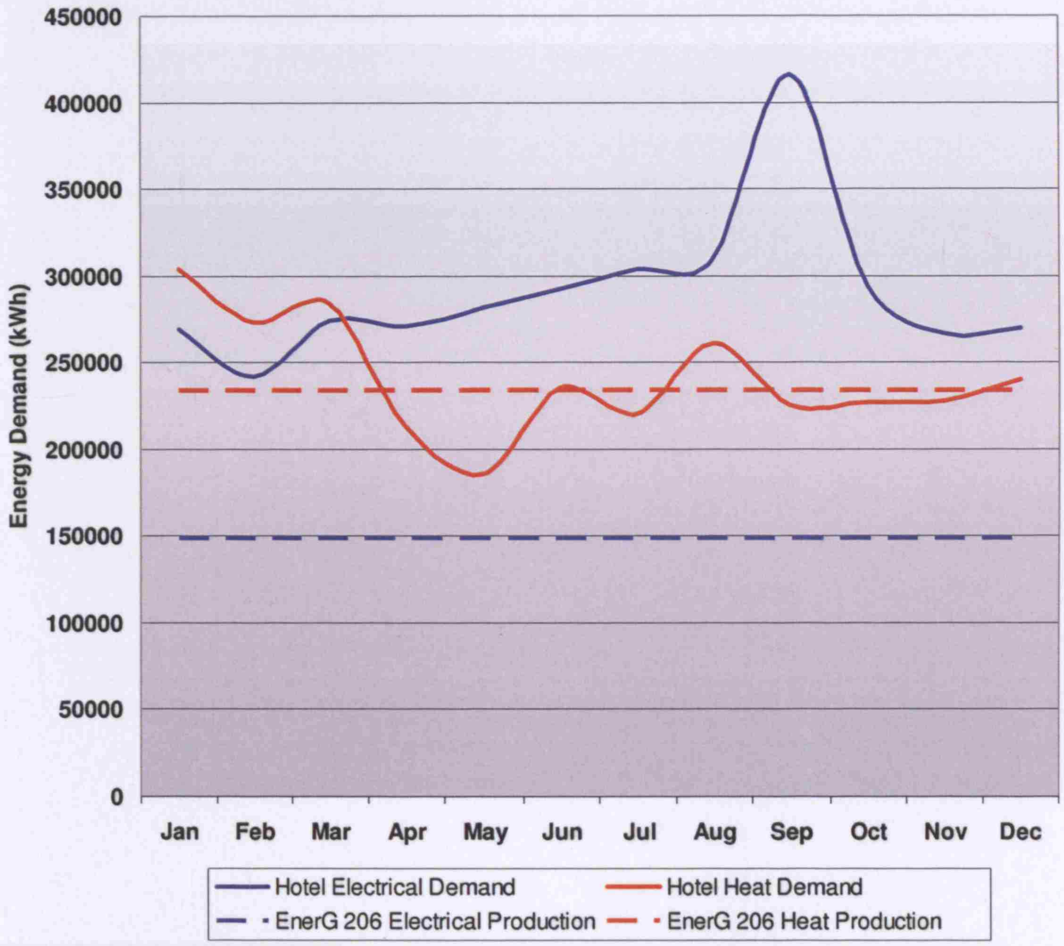

Figure 45 – EnerG 206 CHP Unit Heat and Power Production Characteristics against Measured Heat and Power Demand for Case Study Hotel

Figure 45 shows how the idealised electricity and heat production characteristics of the unit compare to the variation in demand from the hotel throughout the year[15]. It can be seen from the demand/production curves that more heat is produced than electricity, and that the CHP unit has been sized to not exceed the base load heat demand. This requirement not to produce more heat than the hotel can use actually limits the amount of the electrical base load that can be provided by the CHP unit. This in turn limits the carbon and cost savings which can be achieved by using CHP, as electricity is much more carbon-intensive and expensive than gas on a per-unit basis.

[15] Note that the electricity demand characteristics shown are actual measured figures from the hotel, while the heat demand figures were estimated based on the assumptions and calculations carried out in Section 12.6 (page 112). Also, the heat/power generation characteristics of the CHP plant are theoretical output figures for an optimally running unit. Some variation from the exact graph plots should therefore be allowed for when interpreting the results.

8.2 Scenario 2 – Upgrading Size of CHP Plant to EnerG 305 Unit

One way of using small-scale CHP technology to deliver further carbon savings would be to use a larger CHP unit to provide more of the hotel's energy needs and displace more carbon-intensive grid electricity. Appendix 12.16 (page 132) makes a number of modelling assumptions and contains calculations determining the potential savings from installing an EnerG 305 unit (305 kWe, 432 kWt) at the hotel. These are calculated to be a 9% carbon saving and a 0.8% reduction in utility costs relative to the base case.

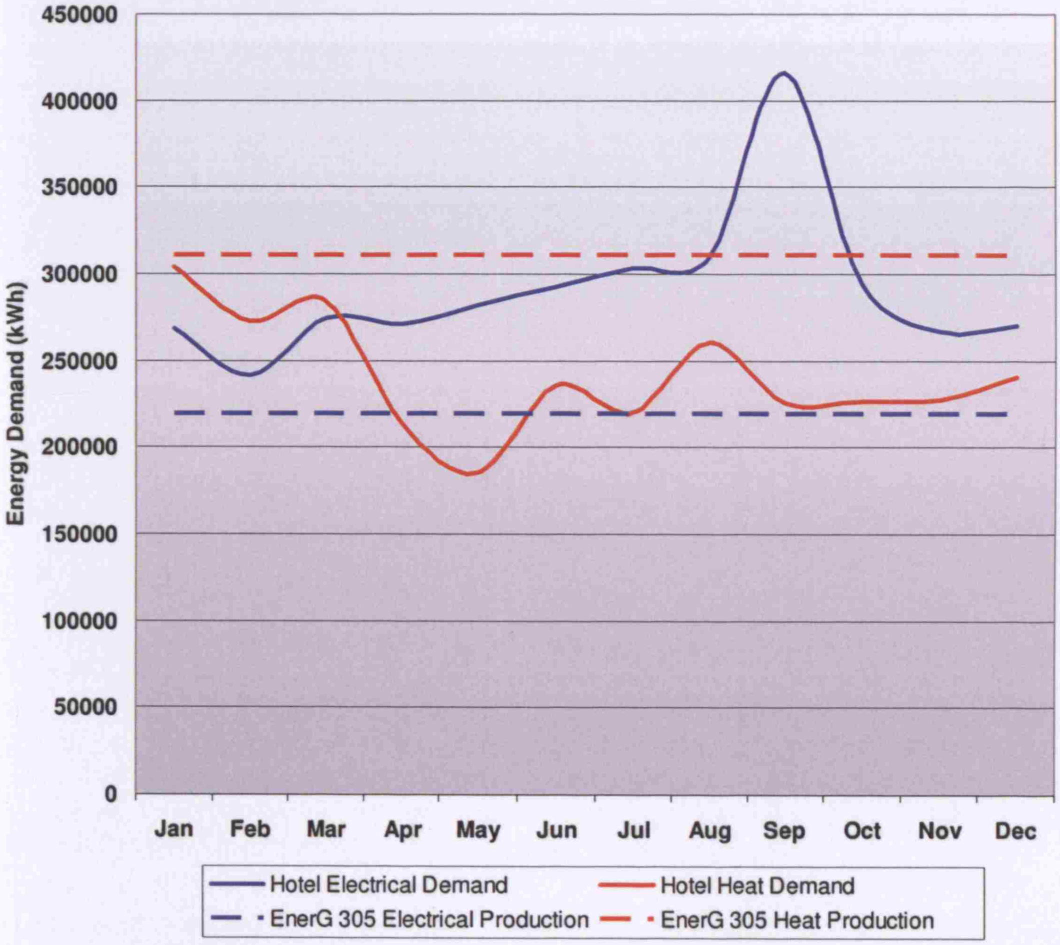

Figure 46 – EnerG 305 CHP Unit Heat and Power Production Characteristics against Measured Heat and Power Demand for Case Study Hotel

Figure 46 shows how the electricity and heat production characteristics of the EnerG 305 unit (Appendix 12.25, page 164) are met to the demand from the hotel throughout the year. It can be seen that relative to the characteristics of the existing EnerG 206 unit (Figure 45, page 72), the new engine produces a much greater portion of the hotel's annual base electrical demand, but at the same time produces much more heat than the hotel requires for most months of the year. This would mean that while reliance on grid electricity supply would be greatly reduced, there would be an excess production of heat to deal with. This is discussed in Section 10.4 (page 93).

8.3 Scenario 3 – Upgrading Size of CHP Plant to EnerG 405 Unit

Using an even larger CHP unit can be shown to deliver further carbon and cost savings. The calculations in Appendix 12.17 (page 136) show that the installation of an EnerG 405 (405 kWe, 606 kWt) unit at the hotel would result in an 18% carbon saving and a 0.1% fall in utility costs relative to the base case.

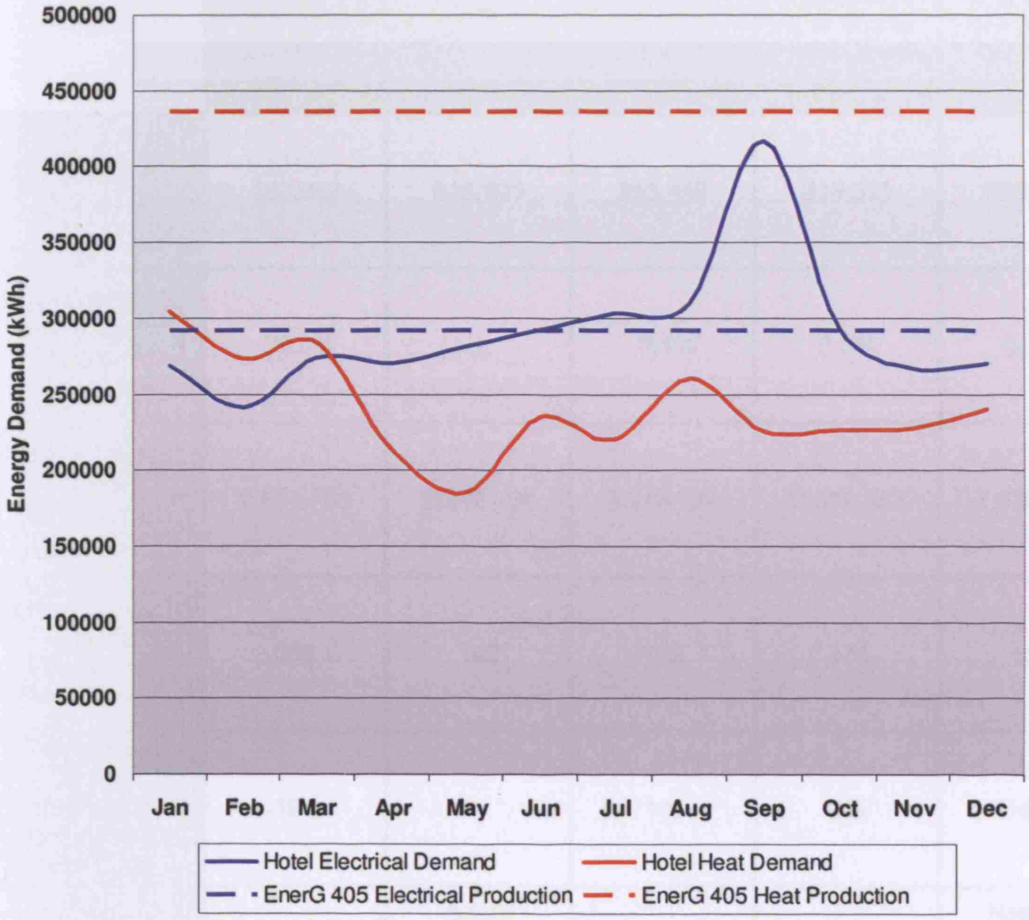

Figure 47 – EnerG 405 CHP Unit Heat and Power Production Characteristics against Measured Heat and Power Demand for Case Study Hotel

Figure 47 shows how the use of an EnerG 405 unit (Appendix 12.26, page 165) would cover the hotel's entire base electricity demand, with some periods of oversupply. However, it can be seen that heat production would be well in excess of demand throughout the year. Methods of dealing with periods of power/heat oversupply to the hotel building are discussed in Section 10.4 (page 93).

8.4 Summary of Carbon Emissions and Utility Cost Savings Resulting From Alternative CHP Energy Provision Scenarios

The potential carbon emissions and utility cost savings calculated from the various scenarios covered are summarised in Table 3.

	Theoretical Performance of Hotel, No CHP Unit (Section 7, page 60)	Base Case, Measured Performance of Hotel Using EnerG 206 CHP Unit	Scenario 1, Improve Reliability of EnerG 206 CHP Unit	Scenario 2, Upgrade to EnerG 305 CHP Unit	Scenario 3, Upgrade to EnerG 405 CHP Unit
Annual Utility Costs (£)	380,062	316,809	318,442	314,396	316,529
% Reduction In Utility Costs Relative to Base Case	-20.0%	-	-0.5%	0.8%	0.1%
Annual Carbon Dioxide Emissions (kgCO2)	2,671,738	2,242,180	2,210,724	2,032,593	1,836,474
Annual Carbon Dioxide Emissions (kgCO2/m2)	232	195	192	176	159
% Reduction In Carbon Emissions Relative to Base Case	-19%	-	1%	9%	18%
Notes	No CHP Unit	Actual Performance of Case Study Hotel, Target 720 Hours Per Month Not Met	Target 720 Hours Per Month Met	Need to Export Excess Heat	Need to Export Excess Power Need to Export Excess Heat

Table 3 – Summary of Carbon Emissions and Utility Cost Savings Resulting from Alternative CHP Energy Provision Scenarios

9 DEMAND SIDE ENERGY REDUCTION

Alternative scenarios for providing heat and power in the building were explored in Section 8 (page 71). This section of the report focuses on examining the carbon and cost savings associated with implementing a variety of demand side energy reduction strategies. Some of the measures mentioned are actively being pursued by the hotel's facilities management staff. The cost-effectiveness and payback periods associated with carrying out these modifications to the building are not considered.

9.1 Lamp Replacement

One area earmarked by the building's facilities management team for targeted energy saving is in the hotel's lighting installation. The atrium and circulation areas which provide access to the guest rooms are lit 24 hours a day by 400 individual 75W lamps. It has been suggested that these could effectively be replaced with 50W lamps while still maintaining acceptable levels of illumination. The 50W bulbs, shown in Figure 48, can be mounted in the same light fitting as the 75W bulbs with no modifications.

Figure 48 – 50W OSRAM Halostar Bulbs, Proposed By Facilities Management as a Direct Replacement for the Existing 75W Bulbs Used In Atrium and Corridor Luminaires

The calculations in Appendix 12.18 (page 140) show that this lamp replacement exercise would result overall electrical energy consumption falling by 3%. This would save the hotel £3076 per year, 1% of the total utility bill. It would also reduce the building's emissions by 21,788 kgCO2, also a 1% saving.

9.2 Bathroom Mirror Heaters

Another area under investigation for demand side reduction is in the electric mirror heaters provided in the guest bedrooms. These use a 60W electric heating element to prevent condensation forming on the surface of the bathroom mirrors as illustrated by the image in Figure 49. The mirror heaters are linked to the guest bedroom door access system mentioned in Section 5.3 (page 41) so that they are only on when the room is occupied. The facilities management team has proposed that the mirror heaters only be operated during the cooler 6 months of the year rather than all year round.

Figure 49 – Example of an Electric Mirror Heater Pad in Operation (Ceetek Electronics Group 2008)

The calculations in Appendix 12.19 (page 145) show that changing the mirror heater operation in this way would reduce overall annual electricity consumption by 0.7%, delivering a cost saving of 0.07% (£225) and a carbon saving of 0.24% (5,447 kgCO_2).

9.3 Mini-Bar Refrigerators

Each of the 200 hotel bedrooms is provided with a mini-bar using conventional vapour-compression refrigeration technology, such as that shown in Figure 50. These typically consume around 0.9 kWh/24h (Appendix 12.27, page 166). One energy saving measure that could be investigated is replacing these units with equivalent mini-bars using thermo-electric (peltier effect) cooling units, which can offer lower energy consumption, in the region of 0.45 kWh/24h (Appendix 12.28, page 167).

Figure 50 – Typical Hotel Mini-Bar Refrigerator Unit (Minibar Systems 2008)

The calculations in Appendix 12.20 (page 150) show that replacing the existing mini-bars with more efficient units would reduce overall annual electricity consumption by 1.1%. The hotel would save £700 annually, 0.2% of annual utility costs, and 8,171 kgCO2, 0.36% of annual emissions.

9.4 Summary of Carbon Emissions and Utility Cost Savings Resulting From Proposed Demand Side Energy Management Strategies

The carbon and utility cost savings calculated from the various demand side reduction strategies are summarised in Table 4. Combined together, the various proposed demand side reduction strategies have the potential to save the hotel £5,451 annually and reduce emissions by 35,406 kgCO2.

	Base Case, Measured Performance of Hotel	Implement Lamp Replacement Strategy	Modify Operation of Mirror Heaters	Replace Mini-Bars with More Efficient Units	Combine All Demand Side Reduction Strategies[16]
Annual Utility Costs (£)	316,809	313,733	316,583	316,108	311,358
% Reduction In Utility Costs Relative to Base Case	-	1.0%	0.07%	0.22%	1.7%
Annual Carbon Dioxide Emissions (kgCO2)	2,242,180	2,220,392	2,236,733	2,234,009	2,206,774
Annual Carbon Dioxide Emissions (kgCO2/m2)	195	193	194	194	191
% Reduction In Carbon Emissions Relative to Base Case	-	1.0%	0.24%	0.36%	1.6%

Table 4 – Summary of Carbon Emissions and Utility Cost Savings Resulting from Implementation of Different Demand Side Energy Reduction Strategies

[16] See Appendix 12.21 (page 155)

9.5 Combining Demand Side Energy Management Measures with Alternative CHP Energy Provision Scenarios

Combining all of the proposed demand side energy reduction strategies with the alternative CHP energy provision scenarios gives the carbon and utility cost savings shown in Table 5.

	Theoretical Performance of Hotel, No CHP Unit	Base Case, Measured Performance of Hotel Using EnerG 206 CHP Unit	Implement All Demand Side Energy Reduction Strategies	Implement All Demand Side Energy Reduction Strategies and Improve Reliability of EnerG 206 CHP Unit	Implement All Demand Side Energy Reduction Strategies and Upgrade to EnerG 305 CHP Unit	Implement All Demand Side Energy Reduction Strategies and Upgrade to EnerG 405 CHP Unit
Annual Utility Costs (£)	380,062	316,809	311,358	312,991	308,945	311,078
% Reduction In Utility Costs Relative to Base Case	-20.0%	-	1.7%	1.2%	2.5%	1.8%
Annual Carbon Dioxide Emissions (kgCO2)	2,671,738	2,242,180	2,206,774	2,175,318	1,997,187	1,801,068
Annual Carbon Dioxide Emissions (kgCO2/m2)	232	195	191	189	173	156
% Reduction In Carbon Emissions Relative to Base Case	-19%	-	2%	3%	11%	20%

Table 5 – Summary of Carbon Emissions and Utility Cost Savings Resulting from Combining Demand Side Energy Reduction Strategies with Alternative CHP Energy Provision Scenarios

10 DISCUSSION AND CONCLUSION

This section compares the measured performance of the case study hotel against industry best practice benchmarks. The contribution of the case study CHP unit to reducing utility costs and carbon emissions is examined, along with the observations made regarding the use of CHP units to provide energy requirements beyond the base load. The implications that these observations may have for the optimum implementation of CHP in UK hotel buildings is discussed, and areas for future research are identified.

10.1 Energy and Water Consumption

Water consumption at the hotel averaged 266 litres/room/day. This is comparable to published consumption data for other European hotels, with Hilton Europe averaging 446 litres/room/day and Scandic averaging 177 litres/room/day (Bohdanowicz & Martinac 2007). The hotel's use of water is therefore within expected tolerances. Unfortunately, the same cannot be said for the hotel's energy use.

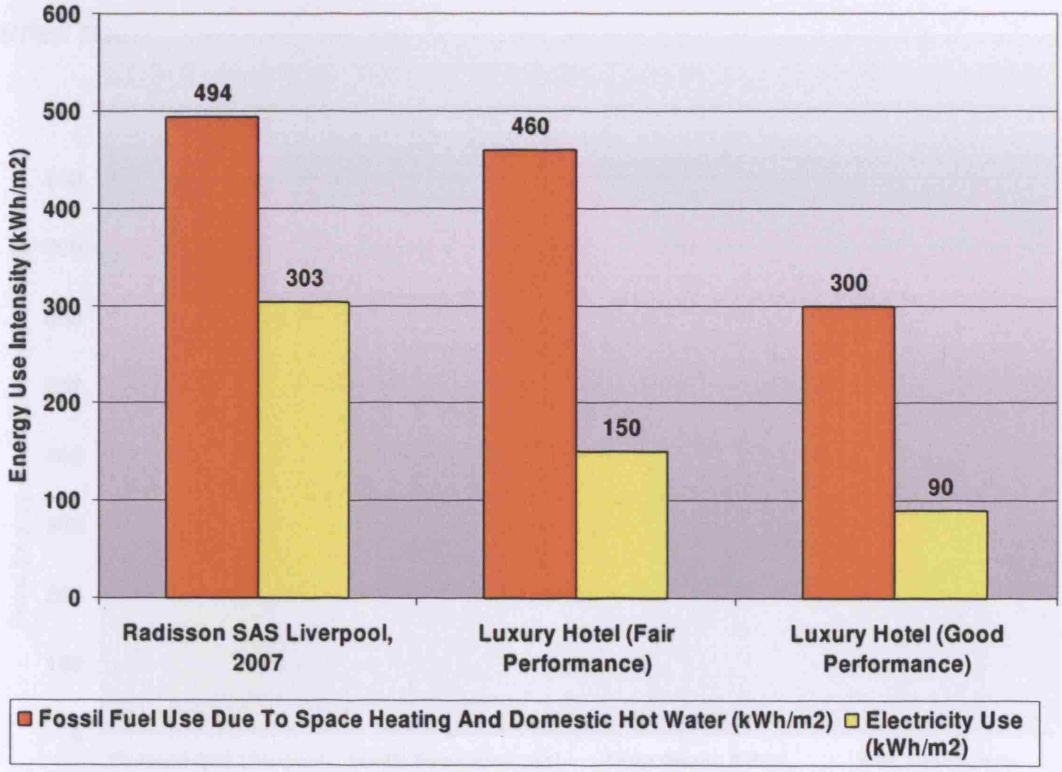

Figure 51 – Case Study Hotel Energy Use Intensity Compared Against Carbon Trust Benchmarks from ECG036 (The Carbon Trust 1999)

Figure 51 places the gas and electricity consumption of the case study building in context against benchmarks from a 300 hotel study (The Carbon Trust 1999). It can be seen that the measured energy use of the building is high compared to that of a 'fair' performing luxury hotel, with a large proportion of the observed difference being due to the electrical load. This suggests that the case study hotel has a large cooling requirement relative to those hotels surveyed as part of the Carbon Trust survey, which is based on 1993 data. It is possible that air-conditioning was not as widespread in 1993 as it is in 2007, which may have skewed the benchmark target towards lower electricity use. UK mean temperatures may have also risen during the interim period. Cooling demand was not investigated as part of this study, but the Radisson SAS Liverpool certainly does condition all of its guest rooms to 21°C when they are occupied (Section 5.4, page 43) which could represent a significant cooling load. This would be a key area to investigate if any future work based on the same building was to be carried out.

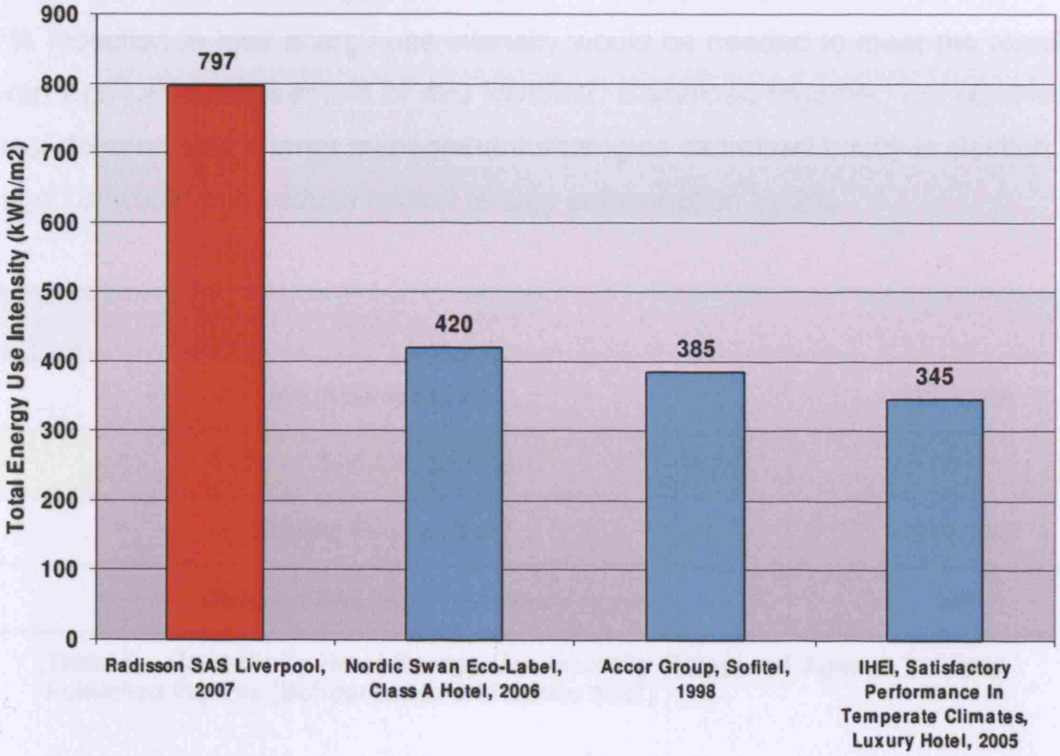

Figure 52 – Case Study Hotel Energy Use Intensity (EUI) Compared Against Industry Best Practice Benchmarks from a Range of Sources (Bohdanowicz & Martinac 2007)

Figure 52, which considers the case study hotel's total energy use intensity (EUI), shows that it compares poorly against a range of other best practice energy performance benchmarks. Notably, the energy consumption of the hotel is more than double that of the 'satisfactory performance in temperate climates, 2005' benchmark for a luxury hotel recommended by the IHEI[17]. It is interesting to note that the use of a CHP unit in this case actually results in a 26% increase in total energy use intensity (Section 7.6, page 70), although this is compensated for by large carbon and cost savings, discussed below in Section 10.2 (page 89). This calls into question whether the benchmark targets take into account the use of CHP plant in hotel buildings or not, something which could be investigated in future studies.

In any case, it is clear that to have any hope of meeting the benchmarks, a massive reduction in energy consumption would be required. For example, a 47% reduction in total energy use intensity would be needed to meet the Nordic Swan Eco-Label requirement of 420 kWh/m2. Combined together, the relatively minor demand side energy management strategies examined briefly in Section 9 (page 78) would only reduce overall energy consumption by 2%.

Source	Total Energy Use Intensity (kWh/m2)
Hilton Europe 2004	129 – 859
Radisson SAS Liverpool, 2007	797
Scandia Europe, 2004	124 – 568
Radisson SAS, 2004 (Average)	281

Table 6 – Case Study Hotel Energy Use Intensity Compared Against Industry Published Figures (Bohdanowicz & Martinac 2007)

Comparing the hotel's energy use with actual published figures from industry is quite revealing. Table 6 shows that the Radisson SAS Liverpool consumes far more energy than the average Radisson SAS hotel, and is on a par with the most energy hungry Hilton properties.

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[17] IHEI, International Hotels Environment Initiative, now part of the ITP, International Tourism Partnership, www.tourismpartnership.org

Overall, the energy performance of the hotel is disappointing; particularly as it was only completed in 2004 and would have been constructed to modern building standards. These results are especially poor when it is considered that the data analysed does not include for the utility consumption of the adjacent health and fitness centre, as explained in Section 5.2 (page 31). The health club contains a pool, sauna, steam room and gym facilities, all of which are energy and water intensive, and all of which are often included in typical luxury hotels. If combined figures for both the hotel and the fitness centre were available, it is likely that the performance comparison with the above benchmarks would be even less favourable.

10.2 Carbon Emissions

The hotel's carbon emissions are benchmarked at 195 $kgCO_2/m^2/year$, as described in Section 6.7 (page 57). This is significantly in excess of what would be expected from a typical UK hotel, which generates 'about 160kg of CO_2 per square meter of floor area' annually (The Carbon Trust 1999). Figure 53 illustrates this comparison.

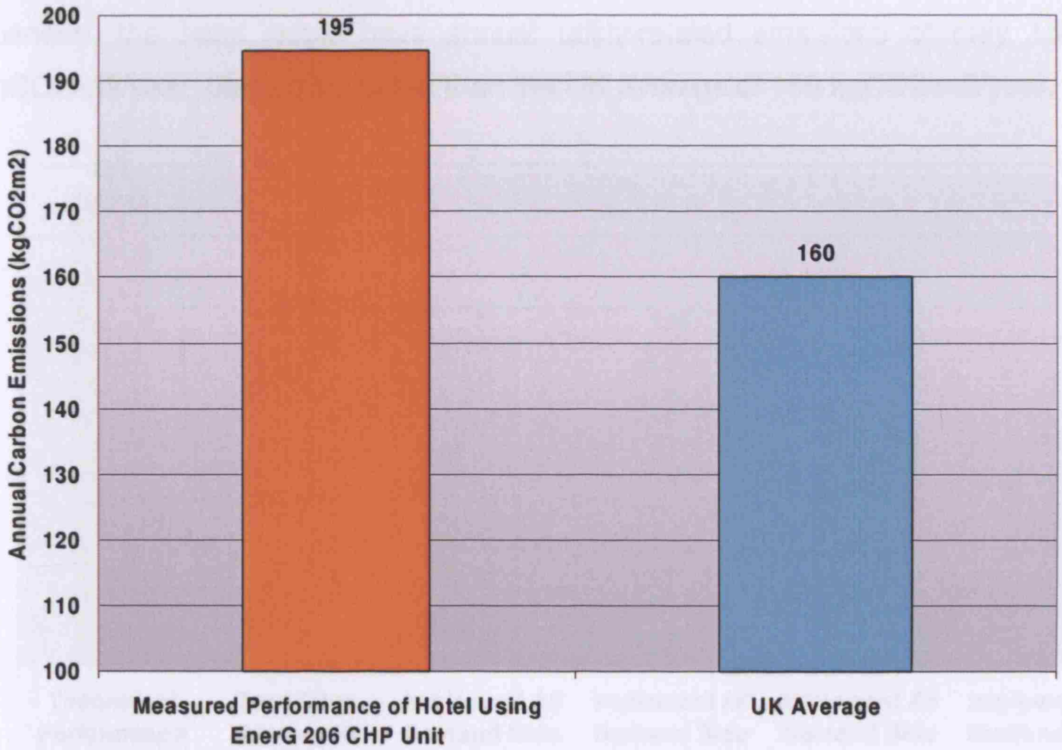

Figure 53 – Comparison of Case Study Hotel Measured Carbon Emissions against UK Average

However, although the carbon performance of the hotel is demonstrably poor, the building's CHP unit does go a long way towards mitigating its environmental impact. As discussed in Section 7.4 (page 68), the carbon emissions from the building would be 232 $kgCO_2/m^2/year$ without the CHP unit, while the actual performance was equivalent to 195 $kgCO_2/m^2/year$. The CHP plant therefore contributes towards a 16% reduction in the hotel's carbon footprint.

The various scenarios covered in Section 8 (page 71) show that small-scale CHP technology has the potential to reduce the carbon emissions rating of the hotel by a further 18.1%. Additionally, Section 9 (page 78) considers the use of demand side energy management measures to potentially deliver a further 1.6% reduction in emissions. Combining the demand side energy reduction strategies with larger, more reliably performing CHP units has the potential to reduce emissions by up to 20% relative to the base case, as shown in Figure 54. In the 20% reduction scenario, the hotel would have annual utility-related emissions of only 156 kgCO2/m2/year, performing better than the UK average of 160 kgCO2/m2/year.

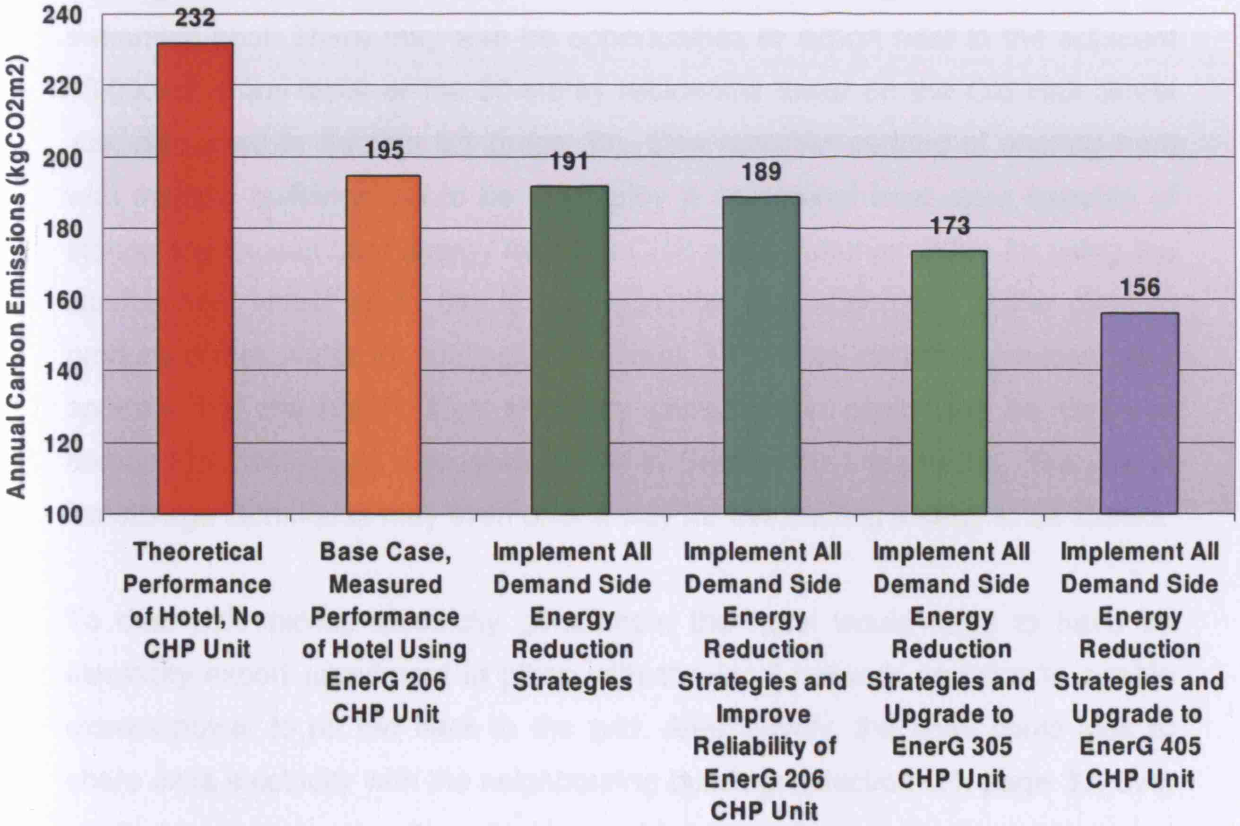

Figure 54 – Comparison of Annual Carbon Emissions Benchmarks for the Hotel under Different Scenarios

Figure 54 shows that the use of larger CHP engines at the case study hotel offers a clear improvement in terms of carbon performance. They do however, become progressively more complex to implement. CHP installations that go beyond base-load heat/power provision suffer from an excess production of electricity and heat during certain periods. The use of an EnerG 305 unit would lead to a significant excess production of heat, while using an EnerG 405 unit to achieve a 20% reduction in emissions would result in periods of oversupply for both heat and electricity.

Heat not used by the hotel could be rejected to atmosphere, but this is essentially wasting the energy. A much more beneficial application would be to export it to the adjacent fitness centre, as mentioned originally in Section 5.2 (page 31). This building is likely to have a large and steady base heating demand due to its swimming pool. There may also be opportunities to export heat to the adjacent 13,000m2 office block or the 30-storey residential tower on the Old Hall Street site, discussed in Section 5.1 (page 30). One possible method of sharing heat with multiple buildings would be to employ a communal heat store capable of storing any excess heat energy from the CHP plant. Another option for using the surplus heat would be to use it in conjunction with absorption chiller plant to produce chilled water for cooling at the hotel. This is an attractive prospect as it appears that the hotel's high electricity consumption could well be down to demand for cooling, as discussed above in Section 10.1 (page 85). The use of ice-storage techniques may even offer a way for this cooling energy to be stored.

To deal with excess electricity generation, the hotel would need to have an electricity export agreement in place with the local network operator to enable excess power to be fed back to the grid. Alternatively, the hotel could look to share extra electricity with the neighbouring buildings (Section 5.1, page 30) over a private-wire network, although this would presumably require the involvement of the site's landlord in the process.

10.3 Utility Costs

Section 7.5 (page 69) shows that the use of small-scale CHP technology saves the hotel £63,253 annually. This represents a 17% saving off the total utilities bill, and an 18.5% saving if only gas and electricity are considered.

Section 8 (page 71) shows that the use of larger CHP engines has the potential to deliver increased reductions in carbon emissions. However, the larger units tested appear to offer no net benefit from a utilities cost perspective. More power and heat is generated, but at the same time, more fuel is used to run the plant. At the per-unit energy prices used in the modelling, any savings made from reducing grid electricity consumption were matched by an increased spend on natural gas.

Section 9 (page 78) shows that applying a number of demand side energy reduction measures can deliver a small, but significant annual cost saving to the hotel of £5,451, or 1.7% of annual utility-costs. Whether or not these measures would ultimately be more cost-effective than making modifications to the CHP plant is outside the scope of this report, but would be a valuable area to investigate in future studies.

10.4 Conclusion

Hotel buildings are extremely energy intensive properties which consequently are very high emitters of carbon dioxide. This report shows that the inclusion of a small-scale CHP unit in a poorly performing UK hotel building can provide a large reduction in carbon emissions, while at the same time greatly reducing energy bills. The report also shows that small energy savings from various demand side energy management techniques can quickly add up to provide significant reductions in both carbon dioxide emissions and utility costs.

As discussed in Section 3.2 (page 12), prescriptive planning regulations in many parts of the UK now require new developments to provide a certain portion of their energy needs from onsite low and zero-carbon technologies. The small-scale CHP unit considered in this report meets 61% of the energy needs of the hotel, which is well in excess of the typical 10-20% target found in Merton-rule-style planning requirements. Admittedly, small-scale CHP using natural gas is a low-carbon technology rather than a strictly renewable technology, but many jurisdictions will accept CHP plant as making a contribution towards 'renewables' targets.

In an intensely competitive, profit driven industry such as the hotel business, cost is often the main driver for design decisions. The analysis carried out in this report shows that a simple CHP installation, sized on the base load of the hotel, makes financial sense, delivering an 18.5% saving on energy costs, while also providing a 16% reduction in carbon dioxide emissions. The inclusion of a base-load CHP plant in a new hotel building, or as a retrofit option for an existing hotel, is therefore an attractive proposition both financially[18] and environmentally. The benefits of using CHP plant to go beyond base load energy requirements however, are less clear-cut.

[18] At the 2007 energy prices described in the report.

As shown in Section 8 (page 71), using CHP plant to go beyond the provision of base heat/power loads can result in greater carbon savings, primarily because the CHP plant then displaces more grid electricity, which has a high carbon content. However, there are no net cost benefits to be obtained, as the reduction in grid electricity use is matched by an increase in natural gas consumption. At the same time, using CHP to go beyond the base load is more complex to implement. This is because options for sharing excess power and heat production during periods of oversupply must be considered in detail. These arrangements have the potential to increase the up-front cost of the CHP installation, making it less attractive to hotel operators unless they are particularly environmentally focused. Many are not, meaning that small-scale CHP units in those cases are essentially limited by economics to providing just for the building's base demand load.

There are a number of situations however, when larger CHP units, providing beyond-base-load energy requirements, could be viable for use in hotels. Resort-style hotel developments, which often have many different buildings with varying occupancy and demand profiles, are one such area. Hotel buildings proposed as part of large multi-use sites are another. In these cases, there is much more scope for sharing heat and power between a number of different buildings. The site as a whole is more likely to have a well diversified heat and power demand profile, as well as a higher total base load for the CHP unit to supply. As a consequence, a higher proportion of the total site wide energy requirements can be met by CHP. This could potentially result in very large carbon savings.

The Old Hall Street scheme, of which the case study hotel forms a part, would have been an ideal site to implement such an arrangement, supplying heat and power to the hotel, the fitness centre, the office block, and the residential tower from a central CHP energy centre. Evidently this option was discounted by the developer at the design stage, which means the opportunity to reduce the whole site's overall carbon emissions in this way was not available.

In conclusion therefore, the discussion of 'optimal implementation' of small-scale CHP plant in a UK hotel building depends very much on whether financial or environmental concerns take precedence. From a financial perspective[19], the inclusion of a CHP unit sized to meet the base load requirements of a hotel is the most attractive proposition, while going beyond base load provision offers no financial benefit. From an environmental perspective[20], CHP should be implemented to displace as much carbon-intensive grid produced electricity as possible, preferably using large units supplying whole sites rather than just individual buildings. In order for this to be achieved however, developments with sufficiently dense heat demands are required.

One way of raising heat demand for CHP, discussed earlier in Section 10.2 (page 89), is to use heat energy to produce chilled water for cooling with absorption chillers, a technique often referred to as tri-generation. Whether or not gas-fuelled tri-generation can actually deliver better carbon savings than using grid electricity to power conventional chillers depends on what figures are used for the carbon intensity of gird electricity in the calculations. This is a highly contentious issue originally sparked by an article in the Building Services Journal penned by James Thonger, an associate director at Arup (Thonger 2007). The article levelled withering criticism at GLA planning policy requiring CHP and tri-generation to be considered in all new developments. At the time of writing the debate continues to rage within the UK building services community and remains largely unresolved.

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[19] At the 2007 energy prices described in the report.

[20] Using the carbon conversion factors for grid electricity described in the report.

10.5 Opportunities for Further Analysis

Modelling combined heat and power installations and their application to individual buildings and multiple-building sites of different scales could easily form the basis for a doctoral level research piece. This report, by necessity, is limited in scope. There are many avenues for further work in this area which could be pursued.

Taking the individual case study building as an example, there were a number of areas which could be explored or further refined. Obtaining actual guest-night data from hotel accounting records, rather than making an informed estimate on visitor numbers would enable a more accurate picture of the emissions per guest-night generated by the operation.

The lack of sub-metering arrangements in place at the hotel meant that it was difficult to determine where energy was being used in the building. The high electricity consumption of the hotel relative to established benchmarks, in particular, warrants further investigation. Installing temporary monitoring equipment at the hotel could better enable any future studies to gain an insight into how the energy is allocated to different end uses, such as heating, lighting, cooling etc. Monitoring equipment could also be set to deliver a greater resolution in energy consumption data, perhaps at half hourly intervals.

Having daily demand profile data in addition to seasonal demands for heat and electricity would allow base heat/power demands to be determined. This would enable a much more robust investigation into the sizing of the existing CHP plant and the implications of using alternative CHP units. Determining the overall cooling demand of the building would also open the door to an investigation into the suitability of using tri-generation at the hotel.

The financial implications of using a CHP plant are clearly of great interest to hotel operators. With fuel prices changing daily, it would be valuable to investigate the economics of how the unit performs under different energy pricing scenarios. The so called 'spark gap' between gas and electricity pricing would be of particular interest in this case. Whole life cycle costing of the case study CHP installation could determine whether or not rising fuel costs make CHP units of different sizes viable or not. Additionally, different arrangements exist for ownership and maintenance of CHP plant. It could for example, be investigated as to whether it is more cost-effective for the hotel to own their own CHP plant, or to buy the directly energy from a CHP supplier who also takes on ownership and maintenance costs.

Finally, future developments in either biomass CHP or hydrogen fuel cell CHP appear to be of great interest, as they offer a way (dependent on many pre-conditions) for CHP technology to become zero-carbon. A detailed investigation into their use in the case study building and a comparison with fossil-fuel fired CHP might provide some useful insights.

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12 APPENDIX

This section contains summaries of the measured performance data taken from case study hotel records, as well as the calculations which underpin the rest of the report. Some further detail on items of interest which could not be fully discussed within the context of the main body of the report are also included for interest.

12.1 Summary of Hotel Metered Utility Data

Table 7 summarises the consumption data taken from the environmental reporting records of the Radisson SAS Liverpool and used in various calculation throughout this report.

Month, 2007	Water Consumption (m3)	Gas Consumption (m3)	Gas Consumption (kWh)	Grid Electricity Consumption (kWh)	CHP Generated Electricity (kWh)	CHP Generated Heat (kWh)	CHP Gas Input (kWh)
January	1,480	48,615	537,443	164,969	104,013	163,300	346,710
February	1,249	47,337	523,307	118,034	123,643	194,120	412,143
March	1,503	51,735	571,925	126,978	147,151	231,027	490,503
April	1,461	39,442	436,030	158,631	112,351	176,391	374,503
May	1,492	36,381	402,188	163,566	118,113	185,437	393,710
June	1,473	41,131	454,709	185,663	106,531	167,254	355,103
July	1,857	36,300	401,297	163,231	140,268	220,220	467,560
August	1,724	48,689	538,262	167,369	142,627	223,924	475,423
September	1,660	37,357	412,978	272,660	143,792	225,753	475,971
October	1,951	43,102	476,495	149,611	144,464	226,808	478,176
November	1,509	37,948	419,511	177,612	89,093	139,875	294,896
December	2,029	47,329	523,221	119,740	150,459	236,221	498,019
Annual Total	19,388	515,366	5,697,366	1,968,064	1,522,505	2,390,330	5,062,719
Monthly Average	1,616	42,947	474,781	164,005	126,875	199,194	421,893

Table 7 – Summary of Metered Utility Consumption Data

Gas consumption was taken from the hotel records in m3. For different energy and carbon calculations it was necessary to convert gas into kWh figures. The conversion factor used to obtain the values shown in Table 7 was 11.055 kWh/m3, which is the value for the energy content of natural gas given in the 2007 Digest of UK Energy Statistics (BERR 2008).

Unfortunately only gas consumption data for the CHP unit during the period October – December was available directly from hotel records. However, as the thermal and electrical outputs from the unit are known for all months of the year, it is possible to establish a realistic figure for gas consumption from the power and/or heat output figures. The manufacturer's own data (Appendix 12.24, page 163) shows that the unit consumes 683 kW of fuel for every 206 kWe and 324 kWt which it generates. This information can be used to back calculate gas input to the CHP unit for the period January – September shown in Table 7.

12.2 Calculation of Number of Guest-Nights

No information was available from the Radisson SAS Liverpool on guest occupancy during the case study year of 2007. In order to build up a picture of the hotel's energy consumption and carbon emissions on a per guest-night basis, a number of assumptions needed to be made in order to arrive at a set of figures for occupancy numbers.

The decision was made to link the occupancy profile of the hotel to the water consumption, as it was felt there would be a good correlation between the number of visitors present at the hotel and the demand for water for cooking meals, showering etc.

The monthly water consumption figures for the hotel were first taken from Appendix 12.1 (page 105) and converted into litres. A benchmarked water consumption figure of 203 litres/guest-night was then used to determine an approximate number of guest nights for each month, as shown in Table 8.

Month, 2007	Water Consumption (m3)	Water Consumption (litres)	Calculated Number of Guest Nights
Jan	1,480	1,480,000	7,291
Feb	1,249	1,249,000	6,153
Mar	1,503	1,503,000	7,404
Apr	1,461	1,461,000	7,197
May	1,492	1,492,000	7,350
Jun	1,473	1,473,000	7,256
Jul	1,857	1,857,000	9,148
Aug	1,724	1,724,000	8,493
Sep	1,660	1,660,000	8,177
Oct	1,951	1,951,000	9,611
Nov	1,509	1,509,000	7,433
Dec	2,029	2,029,000	9,995

Total	95,507

Table 8 – Calculation of Monthly Variation in Hotel Guest-Nights Using Water Consumption Data

The benchmarked figure of 203 litres/guest—night was taken from a study of 111 Scandic hotels (Bohdanowicz & Martinac 2007). This was chosen as the Scandic chain appears to offer hotel facilities in a similar service class to that of the Radisson SAS Liverpool.

It can be seen that the total annual number of guest nights calculated in this way is 95,507. As a quick check it was decided to calculate a theoretical total possible number of guest nights for the hotel building to ensure that this was a realistic figure. The hotel building itself has 200 guest rooms. It was assumed that 'full occupancy' would involve 2 persons per room for a total of 400 guests. If the hotel had 400 guests checked in for 365 days of the year, then this would result in a total annual guest-nights figure of 146,000. The calculated value of 95,507 guest-nights is below this figure, so was deemed suitable for use throughout the rest of the report in the absence of any actual measured data.

12.3 Calculation of Water Demand

The total annual water consumption of the hotel, as shown in Appendix 12.1 (page 105), is 19,388 m3, or 19,388,000 litres. This value can be divided by the number of rooms at the hotel (200) and the total number of days in the year (365) to obtain a consumption figure of 266 litres/room/day. Alternatively, this can be divided by the total number of guest nights calculated in Appendix 12.2 (95,507) to give a value of 203 litres/guest-night. As explained in Appendix 12.2 (page 107) the number of guest-nights is in fact actually back calculated from a benchmark of 203 litres/guest-night, so this value is to be expected.

12.4 Calculation of Gas Demand

The total annual consumption of natural gas at the hotel can be taken from Appendix 12.1 (page 105) as 5,697,366 kWh. This value can then be divided by the hotel's conditioned internal floor area (11,526 m2) and the number of guest nights calculated in Appendix 12.2 (95,507) to obtain performance values of 494 kWh/m2 and 60 kWh/guest-night.

12.5 Calculation of Electricity Demand

Appendix 12.1 (page 105) gives the annual grid electrical consumption of the hotel as 1,968,064 kWh, and the annual electricity produced from the hotel's CHP unit as 1,522,505 kWh. As there is no import/export arrangement between the CHP unit and the grid, all of the electricity produced must be used within the hotel itself. Combining these two figures together gives a total annual electrical consumption of 3,490,569 kWh.

This value can then be divided by the hotel's conditioned internal floor area (11,526 m2) and the calculated number of guest nights (Appendix 12.2, page 107) to obtain performance values of 303 kWh/m2 and 37 kWh/guest-night. If just grid electricity alone is considered, the figures are 171 kWh/m2 and 21 kWh/guest-night.

12.6 Calculation of Heat Demand

The heat energy supplied to the building is generated from the combustion of natural gas in the hotel's boiler plant and the CHP unit. Natural gas is also used for catering purposes. The overall gas consumption for the hotel for each month of the year is already known, and is shown in Appendix 12.1 (page 105). In order to determine how much energy is actually extracted from the gas for heating, rather than catering purposes, the amount of gas used in the CHP unit and the boiler plant must be established, along with their thermal conversion efficiencies.

Natural gas used for catering plays no part in meeting the space heating and hot water heating of the hotel. It must be determined so that it can be excluded from the heat demand estimate. To derive a figure for catering demand, a number of assumptions needed to be made. Published data indicates that preparing 1 food cover in a hotel environment uses 4 – 6 kWh of delivered energy (Bohdanowicz & Martinac 2007). The hotel kitchen uses a combination of gas-fired and electrical appliances. It is difficult to know how much of the energy used in catering comes from gas and how much of the cooking is electrical. A 50:50 split was assumed based on a figure of 4 kWh, giving 2 kWh of gas per food cover. Finally, it was assumed that meals would be served at a rate of 1 food cover per guest-night, based on the guest-night figures determined previously in Appendix 12.2 (page 107). This method gives the monthly catering gas consumption for each month.

The heat output from the CHP unit can actually be taken directly from telemetry data logged in the hotel records (Appendix 12.1, page 105). As there is no heat rejection plant associated with the CHP unit, all of this heat must be used within the building. Even though the heat output from the CHP unit is already known, however, the gas consumption for the CHP unit is still needed to establish how much gas is left over for the boilers. This is also given in Appendix 12.1 (page 105).

The gas input to the CHP unit and the estimated catering gas consumption for each month can be subtracted from the overall total consumption in order to obtain the gas input to the boilers. A boiler efficiency of 80% was then assumed to determine the boiler heat output for each month of the year.

Table 9 summarises the calculation of the total annual heat output from the CHP unit and the boilers.

Month, 2007	Total Gas Consumption (kWh)	Catering Gas (kWh)	CHP Gas Input (kWh)	Boiler Gas Input (kWh)	CHP Heat Output (kWh)	Boiler Heat Output (kWh)	Total Heat Output (kWh)
January	537,443	14,581	346,710	176,152	163,300	140,922	304,222
February	523,307	12,305	412,143	98,858	194,120	79,086	273,206
March	571,925	14,808	490,503	66,614	231,027	53,291	284,318
April	436,030	14,394	374,503	47,133	176,391	37,706	214,097
May	402,188	14,700	393,710	-6,222	185,437	0	185,437
June	454,709	14,512	355,103	85,093	167,254	68,074	235,328
July	401,297	18,296	467,560	-84,559	220,220	0	220,220
August	538,262	16,985	475,423	45,854	223,924	36,683	260,607
September	412,978	16,355	475,971	-79,347	225,753	0	225,753
October	476,495	19,222	478,176	-20,903	226,808	0	226,808
November	419,511	14,867	294,896	109,748	139,875	87,799	227,674
December	523,221	19,990	498,019	5,212	236,221	4,169	240,390
				Total (kWh)	**2,390,330**	**507,731**	**2,898,061**

Table 9 – Calculation of Total Annual Heat Output from CHP Unit and Boiler Plant

This methodology is by necessity, an approximation, and has a number of errors associated with it. The anomalous figures are highlighted in red in Table 9. It would appear that the figure used for catering gas consumption in May is too high. Additionally, there are mismatches between the total gas consumption by the building and the CHP gas input in July, September, and October. There is only a single gas connection to the building, and all gas consumption is metered at the point of entry, so either the total gas consumption for these months is incorrect, or the reported CHP figures are incorrect. In all cases where these errors occurred, the approach taken was to assume the boilers did not fire during these months, and that all heating and hot water demand was produced from the CHP unit.

The total annual heat energy use in the building, as calculated in Table 9, is 2,898,061 kWh. This value can then be divided by the hotel's conditioned internal floor area (11,526 m2) and the number of guest nights calculated in Appendix 12.2 (95,507) to obtain performance values of 251 kWh/m2 and 30 kWh/guest-night.

12.7 Calculation of Total Energy Use Intensity

Electricity and gas consumption metrics can be taken from Appendix 12.5 (page 111) and Appendix 12.4 (page 110) respectively. Combining the values together into a single number for energy consumption gives a total Energy Use Intensity (EUI) value of 797 kWh/m2 or 97 kWh/guest-night.

12.8 Calculation of Total Carbon Footprint

The carbon conversion factors used to determine the overall utility-related emissions from the hotel are summarised below in Table 10. Figures for electricity and gas are based on Defra guidelines (Department for Environment, Food and Rural Affairs 2008b), while the factor for water is taken from an article published in Public Sector & Local Government Building Magazine (Hassell 2007).

Utility	Carbon Conversion Factor
Grid Electricity (Grid Rolling Average, 2002-2006)	0.53702 kgCO2/kWh
Natural Gas	0.206 kgCO2/kWh
Mains Cold Water	0.6 kgCO2/m3

Table 10 – Carbon Conversion Factors for Different Utilities

Carbon emissions generated from grid electricity were calculated using the 'Grid Rolling Average' figure in line with Defra guidelines (Department for Environment, Food and Rural Affairs 2008a) as opposed to the 'Long Term Marginal Average' figure from the same document. The carbon emissions associated with producing electricity and heat from the CHP plant are included in the natural gas consumption figure. As no heat or electricity is exported from the site to other users the CHP plant emissions were not broken down separately. Applying the required conversion factors to the metered utility data summarised in Appendix 12.1 (page 105) gives the carbon emissions figures below in Table 11.

Month, 2007	Water (kgCO2)	Gas (kgCO2)	Grid Electricity (kgCO2)	Total Utility-related Emissions (kgCO2)
January	888	110,713	88,592	200,193
February	749	107,801	63,387	171,937
March	902	117,817	68,190	186,908
April	877	89,822	85,188	175,887
May	895	82,851	87,838	171,584
June	884	93,670	99,705	194,259
July	1,114	82,667	87,658	171,440
August	1,034	110,882	89,881	201,797
September	996	85,074	146,424	232,493
October	1,171	98,158	80,344	179,673
November	905	86,419	95,381	182,706
December	1,217	107,784	64,303	173,304
Total (kgCO2)	11,633	1,173,657	1,056,890	**2,242,180**

Table 11 – Calculation of Utility-related CO2 Emissions from Case Study Hotel

It can be seen from Table 11 that the overall utility-related carbon emissions from the hotel total 2,242,180 kgCO2. This figure can then be divided by the hotel's conditioned internal floor area (11,526 m2) and the calculated number of guest nights (see occupancy calculation in Appendix 12.2, page 107) to benchmark the carbon emissions at 195 kgCO2/m2, or 23 kgCO2/guest-night.

12.9 Calculation of Total Utility Costs

Hotel records were used to determine the unit charges paid for each utility, which are summarised below in Table 12.

Utility	Price Tariff
Water	£1.218 / m3
Gas	£0.0244 / kWh
Grid Electricity, Day	Jan - Feb, £0.0935 / kWh March - Dec, £0.0696 / kWh
Grid Electricity, Night	Jan - Feb, £0.0456 / kWh March - Dec, £0.0384 / kWh
CHP Generated Electricity	£0.02 / kWh

Table 12 – Summary of Utility Pricing Tariffs Paid by Radisson SAS Liverpool During 2007

The hotel keeps separate records of how much electricity is consumed at day rate charges and much at night rate charges. This is because daytime electricity is charged by the energy provider at one tariff from 7:00 – 00:00 and at a separate, lower tariff between 00:00 – 7:00. Table 13 below summarises the split.

Month, 2007	Grid Electricity Consumption, Day (kWh)	Grid Electricity Consumption, Night (kWh)
January	119,955	45,014
February	85,755	32,279
March	99,385	27,593
April	103,534	55,097
May	120,330	43,236
June	141,136	44,527
July	123,516	39,715
August	126,952	40,417
September	118,342	154,318
October	115,538	34,073
November	125,270	52,342
December	88,288	31,452

Table 13 – Summary of Split between Day Rate and Night Rate Electricity Consumption Taken from Hotel Records

The per-unit costs in Table 12 were applied to the electricity consumption rates from Table 13 and the metered gas and water utility data summarised in Appendix 12.1 (page 105) to calculate the total monthly utility costs, shown in Table 14.

Month, 2007	Water (£)	Gas (£)	Grid Electricity, Day (£)	Grid Electricity, Night (£)	CHP Generated Electricity (£)	Total Utility Related Costs (£)
January	£1,803	£13,114	£11,216	£2,053	£2,080	£30,265
February	£1,521	£12,769	£8,018	£1,472	£2,473	£26,253
March	£1,831	£13,955	£6,917	£1,060	£2,943	£26,705
April	£1,779	£10,639	£7,206	£2,116	£2,247	£23,987
May	£1,817	£9,813	£8,375	£1,660	£2,362	£24,028
June	£1,794	£11,095	£9,823	£1,710	£2,131	£26,553
July	£2,262	£9,792	£8,597	£1,525	£2,805	£24,981
August	£2,100	£13,134	£8,836	£1,552	£2,853	£28,474
September	£2,022	£10,077	£8,237	£5,926	£2,876	£29,137
October	£2,376	£11,626	£8,041	£1,308	£2,889	£26,242
November	£1,838	£10,236	£8,719	£2,010	£1,782	£24,585
December	£2,471	£12,767	£6,145	£1,208	£3,009	£25,600
Total (£)	£23,615	£139,016	£100,129	£23,599	£30,450	**£316,809**

Table 14 – Breakdown of Utility Costs Paid By Hotel During 2007

The figures in Table 14 were cross checked against the hotel's own accounting information, and one discrepancy was found. The gas utility provider (EDF Energy) actually converts natural gas from m3 to kWh at a rate of 10.83 kWh/m3 rather than using the 11.055 kWh/m3 figure used in this report. This means that there is a £2,740 difference between the utility costs calculated above and the actual accounts. This was judged to be negligible for the purposes of this report's investigation into the optimum implementation of CHP in hotels.

It can be seen from Table 14 that the total annual expenditure on utilities is £316,809. Focussing just on gas and electricity reduces this figure to £293,194. The hotel's conditioned internal floor area (11,526 m2) and the number of guest-nights calculated in Appendix 12.2) (95,507) can be used with these figures to derive cost benchmarks for the hotel. Hotel utility costs can be expressed as

£27.49/m2 or £3.32/guest-night. If water costs are excluded and the focus is purely on gas and grid electricity, then the figures become £25.44/m2 or £3.07/guest-night.

12.10 Calculation of Grid Electrical Consumption for an Identical Hotel without the CHP Unit

An identical building to the case study hotel, without a CHP unit would need to source the equivalent electricity demand previously met by the CHP plant from the grid instead.

Month, 2007	Previous CHP Generated Electricity (kWh)	Previous Grid Electricity Consumption (kWh)	Grid Electricity Consumption If CHP Unit Is Removed (kWh)
January	104,013	164,969	268,982
February	123,643	118,034	241,677
March	147,151	126,978	274,129
April	112,351	158,631	270,982
May	118,113	163,566	281,679
June	106,531	185,663	292,194
July	140,268	163,231	303,499
August	142,627	167,369	309,996
September	143,792	272,660	416,452
October	144,464	149,611	294,075
November	89,093	177,612	266,705
December	150,459	119,740	270,199
Total	1,522,505	1,968,064	3,490,569

Table 15 – Calculation of Hotel Electrical Consumption for No-CHP Case with Equivalent Electricity Provision Sourced from the Grid

Table 15 shows that annual grid electricity demand would increase for the no-CHP case from 1,968,064 kWh to 3,490,569 kWh. It can therefore be said that the use of a CHP unit in this case saves the hotel 44% on their annual electricity demand. The overall electrical energy consumed by the hotel would remain the same at 303 kWh/m2 or 37 kWh/guest-night, but this would need to come entirely from the grid.

12.11 Calculation of Gas Consumption for an Identical Hotel without the CHP Unit

An identical hotel building to the case study hotel, without the CHP unit installed, would provide heat within the building in a different fashion. The level of natural gas consumption would also differ. The split between natural gas for catering, the CHP unit, and the boiler plant, was previously discussed in Appendix 12.6 (page 112).

Without a CHP unit, the demand for natural gas for catering would remain unchanged, and the gas previously used by the CHP unit would no longer be consumed. The total heat demand for the building, calculated in Appendix 12.6 (page 112) as 2,898,061 kWh, would remain unchanged. However, this heating demand would need to be met in its entirety by the boiler plant, rather than by a combination of the boilers and the CHP unit. The gas consumption resulting from this can be back calculated from the assumed thermal efficiency of the boilers (80%). Table 16 summarises the calculation.

Month, 2007	Total Heat Output Required, Unchanged (kWh)	Resulting Gas Consumption By Boilers, 80% Efficient (kWh)	Gas Consumption For Catering, Remains Unchanged (kWh)	New Total Gas Consumption (kWh)
January	304,222	380,277	14,581	394,858
February	273,206	341,508	12,305	353,813
March	284,318	355,398	14,808	370,206
April	214,097	267,622	14,394	282,016
May	185,437	231,796	14,700	246,496
June	235,328	294,160	14,512	308,673
July	220,220	275,275	18,296	293,571
August	260,607	325,759	16,985	342,744
September	225,753	282,191	16,355	298,546
October	226,808	283,510	19,222	302,732
November	227,674	284,592	14,867	299,459
December	240,390	300,488	19,990	320,478
			Total	3,813,591

Table 16 – Calculation of Hotel Gas Consumption if CHP Plant is Removed and Equivalent Heating Demand Supplied Entirely by Boiler Plant

Table 16 shows a total annual gas consumption of 3,813,591 kWh compared to a previous value of 5,697,366 kWh taken from Appendix 12.1 (page 105). The new figure therefore represents 33% fall in overall consumption relative to the original case. Dividing the new value by the hotel's conditioned internal floor area (11,526 m2) and the number of guest nights calculated in Appendix 12.2 (95,507) gives performance values of 331 kWh/m2 and 40 kWh/guest-night.

12.12 Contribution of CHP Unit to Meeting Total Energy Demand

The total annual heat demand of the hotel building can be taken from Appendix 12.6 (page 112) as 2,898,061 kWh. The total annual electrical demand can be taken from Appendix 12.1 (page 105) as 3,490,569 kWh. Combined together, this gives a total annual energy demand of 6,388,630 kWh.

Appendix 12.1 (page 105) shows that the total heat energy provided annually by the CHP unit is 2,390,330 kWh, while the total annual electricity production is 1,522,505 kWh. Combining these values together shows that the CHP unit contributes 3,912,835 kWh towards meeting the hotel's energy demands. As a percentage, therefore, it can be said that the CHP unit contributed 61% of the total measured energy demand of the hotel during 2007.

12.13 Contribution of CHP Unit to Reducing Carbon Footprint

Appendix 12.10 (page 121) and Appendix 12.11 (page 122) show how monthly gas and grid electrical consumption would be different for an identical hotel building without a CHP unit installed. Assuming water demand would be identical, these revised figures can be used with the carbon conversion factors originally described in Appendix 12.8 (page 116) to obtain a figure for the carbon footprint of the no-CHP case, as shown below in Table 17.

Month, 2007	Water (kgCO2)	Gas (kgCO2)	Grid Electricity (kgCO2)	Total Utility-related Emissions (kgCO2)
January	888	81,341	144,449	226,678
February	749	72,886	129,785	203,420
March	902	76,262	147,213	224,377
April	877	58,095	145,523	204,495
May	895	50,778	151,267	202,941
June	884	63,587	156,914	221,384
July	1,114	60,476	162,985	224,575
August	1,034	70,605	166,474	238,114
September	996	61,500	223,643	286,140
October	1,171	62,363	157,924	221,457
November	905	61,689	143,226	205,820
December	1,217	66,019	145,102	212,338
Total (kgCO2)	11,633	785,600	1,874,505	**2,671,738**

Table 17 – Calculation of Utility-related CO2 Emissions for No-CHP Case

The no-CHP case has annual emissions of 2,671,738 kgCO2, versus only 2,242,180 kgCO2 for the base case (Appendix 12.8, page 116). The CHP unit can therefore be said to save the hotel 16% on its annual carbon emissions. As with the original carbon footprint calculation, the hotel's conditioned internal floor area (11,526 m2) and the number of guest-nights calculated in Appendix 12.2 (95,507) can be used to derive a CO2 emissions rating for the hotel. The carbon footprint for the no-CHP case can be expressed as either 232 kgCO2/m2, or 28 kgCO2/guest-night.

12.14 Contribution of CHP Unit to Reducing Energy Costs

Appendix 12.10 (page 121) and Appendix 12.11 (page 122) show how monthly gas consumption and grid electrical consumption would differ for an identical building to the case study hotel without a CHP unit installed. For the purposes of determining the utility costs for the no-CHP case, the additional grid electrical demand was allocated on an hourly pro-rata basis to give the day/night electrical consumption split shown below in Table 18.

Month, 2007	Grid Electricity Consumption, Day (kWh)	Grid Electricity Consumption, Night (kWh)
January	193,631	75,351
February	173,335	68,342
March	203,617	70,512
April	183,116	87,866
May	203,993	77,686
June	216,595	75,599
July	222,873	80,627
August	227,979	82,017
September	220,195	196,257
October	217,867	76,208
November	188,378	78,327
December	194,863	75,336

Table 18 – Breakdown of Monthly Day/Night Rate Electricity Consumption for No-CHP Case with Equivalent Electrical Demand Supplied From the Grid

The new electrical consumption values in Table 18, the new gas consumption values in Appendix 12.11 (page 122), and the original water demand values can be used along with the per-unit utility charges originally described in Appendix 12.9 (page 118) to obtain a new figure for the total annual expenditure on utilities, as shown in Table 19.

Month, 2007	Water (£)	Gas (£)	Grid Electricity, Day (£)	Grid Electricity, Night (£)	CHP Generated Electricity (£)	Total Utility-related Costs (£)
January	£1,803	£12,855	£18,104	£3,436	£0	£36,198
February	£1,521	£12,517	£16,207	£3,116	£0	£33,362
March	£1,831	£13,680	£14,172	£2,708	£0	£32,390
April	£1,779	£10,429	£12,745	£3,374	£0	£28,328
May	£1,817	£9,620	£14,198	£2,983	£0	£28,618
June	£1,794	£10,876	£15,075	£2,903	£0	£30,648
July	£2,262	£9,599	£15,512	£3,096	£0	£30,468
August	£2,100	£12,875	£15,867	£3,149	£0	£33,991
September	£2,022	£9,878	£15,326	£7,536	£0	£34,762
October	£2,376	£11,397	£15,164	£2,926	£0	£31,864
November	£1,838	£10,034	£13,111	£3,008	£0	£27,991
December	£2,471	£12,515	£13,562	£2,893	£0	£31,442
Total (£)	£23,615	£136,276	£179,043	£41,129	£0	**£380,062**

Table 19 – Breakdown of Utility Costs at Case Study Hotel for no-CHP case

The total annual expenditure on utilities for the no-CHP case can be seen to be £380,062 per year, versus the base case spend of £316,809 (Appendix 12.9, page 118). This use of CHP in this case therefore offers a 17% saving. Focussing just on gas and electricity gives expenditures of 356,448 for the no-CHP case and 293,194 for the case study building with the CHP unit. The saving just for gas and electricity therefore is 18.5%. The hotel's conditioned internal floor area (11,526 m2) and the number of guest-nights calculated in Appendix 12.2 (95,507) can be used with these figures to derive cost benchmarks for the no-CHP case. These can expressed as £32.97/m2 or £3.98/guest-night overall. Alternatively, just for gas and electricity, the figures would equate to £30.93/m2 or £3.73/guest-night.

12.15 Calculation for Improving Reliability of Existing EnerG 206 CHP Unit

For the purposes of this calculation, it is assumed that the reliability of the CHP unit could be improved such that the plant was able to run for the scheduled 720 hours a month, with only 10 hours a month set aside for regular maintenance. The current installation comprises an EnerG 206 unit, producing 206 kWe and 324 kWt for a fuel input of 683 kW (Appendix 12.24, page 163). Running the unit for 720 hours a month would elevate production of electricity to a constant 148,320 kWh. Heat production would increase to 233,280 kWh a month, while the gas consumed by the CHP unit would be steady at 491,770 kWh per month. It is assumed that the increase in electricity production from the CHP unit would displace an equal amount of grid electricity. Likewise, the increase in heat produced by the CHP unit would reduce the requirement for the boilers to run, reducing gas consumption. In line with the heat demand calculations in Appendix 12.6 (page 112), the efficiency of the boiler plant was assumed to be 80% for calculating the reduction in boiler gas demand. The resulting changes in the gas and electricity consumption are summarised in Table 20.

Month, 2007	Power Demand (kWh)	Heat Demand (kWh)	Gas Consumption (kWh)	Grid Electricity Consumption (kWh)	CHP Generated Electricity (kWh)	CHP Generated Heat (kWh)	CHP Gas Input (kWh)
January	268,982	304,222	595,018	120,662	148,320	233,280	491,760
February	241,677	273,206	553,973	93,357	148,320	233,280	491,760
March	274,129	284,318	570,366	125,809	148,320	233,280	491,760
April	270,982	214,097	482,176	122,662	148,320	233,280	491,760
May	281,679	185,437	446,656	133,359	148,320	233,280	491,760
June	292,194	235,328	508,833	143,874	148,320	233,280	491,760
July	303,499	220,220	493,731	155,179	148,320	233,280	491,760
August	309,996	260,607	542,904	161,676	148,320	233,280	491,760
September	416,452	225,753	498,706	268,132	148,320	233,280	491,760
October	294,075	226,808	502,892	145,755	148,320	233,280	491,760
November	266,705	227,674	499,619	118,385	148,320	233,280	491,760
December	270,199	240,390	520,638	121,879	148,320	233,280	491,760

Table 20 – Summary of Hotel Gas and Electrical Consumption if Reliability of Existing EnerG 206 CHP Unit can be Improved to Give Constant 720 Hours/Month Operation

The new grid electrical consumption can be allocated on an hourly pro-rata basis to give the day/night electrical consumption split shown below in Table 21.

Month, 2007	Grid Electricity Consumption, Day (kWh)	Grid Electricity Consumption, Night (kWh)
January	85,469	35,193
February	66,128	27,229
March	89,115	36,694
April	86,886	35,776
May	94,463	38,896
June	101,911	41,963
July	109,918	45,261
August	114,521	47,156
September	189,927	78,205
October	103,243	42,512
November	83,856	34,529
December	86,331	35,548

Table 21 – Summary of Split Between Day Rate and Night Rate Electricity Consumption if Reliability of Existing EnerG 206 CHP Unit can be Improved to Give Constant 720 Hours/Month Operation

Assuming water demand remains the same as in Appendix 12.1 (page 105), the gas and electricity consumption values from Table 20 (page 128) can be used along with the per-unit utility charges originally described in Appendix 12.9 (page 118) to obtain a new figure for the total annual expenditure on utilities, as shown in Table 22.

Month, 2007	Water (£)	Gas (£)	Grid Electricity, Day (£)	Grid Electricity, Night (£)	CHP Generated Electricity (£)	Total Utility Related Costs (£)
January	£1,803	£14,518	£7,991	£1,605	£2,966	£28,884
February	£1,521	£13,517	£6,183	£1,242	£2,966	£25,429
March	£1,831	£13,917	£6,202	£1,409	£2,966	£26,325
April	£1,779	£11,765	£6,047	£1,374	£2,966	£23,932
May	£1,817	£10,898	£6,575	£1,494	£2,966	£23,750
June	£1,794	£12,416	£7,093	£1,611	£2,966	£25,880
July	£2,262	£12,047	£7,650	£1,738	£2,966	£26,664
August	£2,100	£13,247	£7,971	£1,811	£2,966	£28,094
September	£2,022	£12,168	£13,219	£3,003	£2,966	£33,379
October	£2,376	£12,271	£7,186	£1,632	£2,966	£26,431
November	£1,838	£12,191	£5,836	£1,326	£2,966	£24,157
December	£2,471	£12,704	£6,009	£1,365	£2,966	£25,515
Total (£)	£23,615	£151,658	£87,962	£19,610	£35,597	**£318,442**

Table 22 – Breakdown of Utility Costs at Case Study Hotel if Reliability of Existing EnerG 206 CHP Unit can be Improved to Give Constant 720 Hours/Month Operation

Assuming water demand would remain identical, the revised figures for gas and electrical consumption taken from Table 20 (page 128) can also be used with the carbon conversion factors originally described in Appendix 12.8 (page 116). This gives a revised figure for the carbon footprint of the hotel as shown below in Table 23.

Month, 2007	Water ($kgCO_2$)	Gas ($kgCO_2$)	Grid Electricity ($kgCO_2$)	Total Utility Related Emissions ($kgCO_2$)
January	888	122,574	64,798	188,260
February	749	114,119	50,135	165,002
March	902	117,495	67,562	185,959
April	877	99,328	65,872	166,077
May	895	92,011	71,616	164,523
June	884	104,820	77,263	182,967
July	1,114	101,708	83,334	186,157
August	1,034	111,838	86,823	199,696
September	996	102,733	143,992	247,722
October	1,171	103,596	78,273	183,040
November	905	102,922	63,575	167,402
December	1,217	107,251	65,451	173,920
Total ($kgCO_2$)	11,633	1,280,395	918,696	**2,210,724**

Table 23 – Calculation of Utility-related CO2 Emissions if Reliability of Existing EnerG 206 CHP Unit can be Improved to Give Constant 720 Hours/Month Operation

Overall, relative to the base case, annual expenditure on utilities rises slightly from £316,809 to £318,442, an increase of 0.5%. At the same time however, annual utility-related carbon emissions fall from 2,242,180 $kgCO_2$ to 2,210,724 $kgCO_2$, a 1% saving.

12.16 Calculation for Upgrading Size of CHP Plant to EnerG 305 Unit

This calculation looks at the financial and carbon emissions savings that could result from the installation of a larger CHP unit at the hotel. The current installation comprises an EnerG 206 unit, producing 206 kWe and 324 kWt for a gas input of 683 kW (Appendix 12.24, page 163). This scenario investigates the use of an EnerG 305 unit, producing 305 kWe and 432 kWt for every 976 kW of gas (Appendix 12.25, page 164).

By assuming that the unit runs at a constant rate of 720 hours per month, the resulting changes to the building's gas and electricity consumption can be calculated. The extra CHP-produced electricity would displace an equal amount of grid electricity, and the extra heat produced would reduce the gas input to the boilers. In line with the heat demand calculations in Appendix 12.6 (page 112), the efficiency of the boiler plant was assumed to be 80% - this was used to calculate the reduction in boiler gas demand from the increase in CHP-produced heat. The resulting changes in consumption can be summarised in Table 24.

Month, 2007	Power Demand (kWh)	Heat Demand (kWh)	Gas Consumption (kWh)	Grid Electricity Consumption (kWh)	CHP Generated Electricity (kWh)	CHP Generated Heat (kWh)	CHP Gas Input (kWh)
January	268,982	304,222	708,778	49,382	219,600	311,040	702,720
February	241,677	273,206	667,733	22,077	219,600	311,040	702,720
March	274,129	284,318	684,126	54,529	219,600	311,040	702,720
April	270,982	214,097	595,936	51,382	219,600	311,040	702,720
May	281,679	185,437	560,416	62,079	219,600	311,040	702,720
June	292,194	235,328	622,593	72,594	219,600	311,040	702,720
July	303,499	220,220	607,491	83,899	219,600	311,040	702,720
August	309,996	260,607	656,664	90,396	219,600	311,040	702,720
September	416,452	225,753	612,466	196,852	219,600	311,040	702,720
October	294,075	226,808	616,652	74,475	219,600	311,040	702,720
November	266,705	227,674	613,379	47,105	219,600	311,040	702,720
December	270,199	240,390	634,398	50,599	219,600	311,040	702,720

Table 24 – Gas and Electricity Demand if EnerG 305 CHP Unit is Installed

The new grid electrical consumption can be allocated on an hourly pro-rata basis to give the day/night electrical consumption split shown below in Table 25.

Month, 2007	Grid Electricity Consumption, Day (kWh)	Grid Electricity Consumption, Night (kWh)
January	34,979	14,403
February	15,638	6,439
March	38,625	15,904
April	36,396	14,986
May	43,973	18,106
June	51,421	21,173
July	59,428	24,471
August	64,031	26,366
September	139,437	57,415
October	52,753	21,722
November	33,366	13,739
December	35,841	14,758

Table 25 – Summary of Split Between Day Rate and Night Rate Electricity Consumption if EnerG 305 CHP Unit is Installed

Assuming water demand remains the same as in Appendix 12.1 (page 105); the new values can be used along with the per-unit utility charges originally described in Appendix 12.9 (page 118) to obtain a new figure for the total annual expenditure on utilities, as shown in Table 26.

Month, 2007	Water (£)	Gas (£)	Grid Electricity, Day (£)	Grid Electricity, Night (£)	CHP Generated Electricity (£)	Total Utility-related Costs (£)
January	£1,803	£17,294	£3,271	£657	£4,392	£27,416
February	£1,521	£16,293	£1,462	£294	£4,392	£23,962
March	£1,831	£16,693	£2,688	£611	£4,392	£26,214
April	£1,779	£14,541	£2,533	£575	£4,392	£23,821
May	£1,817	£13,674	£3,060	£695	£4,392	£23,639
June	£1,794	£15,191	£3,579	£813	£4,392	£25,769
July	£2,262	£14,823	£4,136	£940	£4,392	£26,552
August	£2,100	£16,023	£4,457	£1,012	£4,392	£27,983
September	£2,022	£14,944	£9,705	£2,205	£4,392	£33,268
October	£2,376	£15,046	£3,672	£834	£4,392	£26,320
November	£1,838	£14,966	£2,322	£528	£4,392	£24,046
December	£2,471	£15,479	£2,495	£567	£4,392	£25,404
Total (£)	£23,615	£184,967	£43,379	£9,730	£52,704	**£314,396**

Table 26 – Breakdown of Utility Costs at Case Study Hotel if EnerG 305 CHP Unit is Installed

Assuming water demand would remain identical, the revised figures for gas and electrical consumption taken from Table 24 (page 132) can be used with the carbon conversion factors originally described in Appendix 12.8 (page 116). This gives a revised figure for the carbon footprint of the hotel as shown below in Table 27.

Month, 2007	Water (kgCO2)	Gas (kgCO2)	Grid Electricity (kgCO2)	Total Utility-related Emissions (kgCO2)
January	888	146,008	26,519	173,415
February	749	137,553	11,856	150,158
March	902	140,930	29,283	171,115
April	877	122,763	27,593	151,233
May	895	115,446	33,338	149,679
June	884	128,254	38,984	168,122
July	1,114	125,143	45,055	171,313
August	1,034	135,273	48,544	184,852
September	996	126,168	105,713	232,877
October	1,171	127,030	39,995	168,195
November	905	126,356	25,296	152,558
December	1,217	130,686	27,173	159,076
Total (kgCO2)	11,633	1,561,610	459,350	2,032,593

Table 27 – Calculation of Utility-related CO2 Emissions if EnerG 305 CHP Unit is Installed

Overall, relative to the base case, annual expenditure on utilities falls from £316,809 to £314,396, a saving of 0.8%. At the same time, annual utility-related carbon emissions fall from 2,242,180 kgCO2 to 2,032,593 kgCO2, a 9% saving.

12.17 Calculation for Upgrading Size of CHP Plant to EnerG 405 Unit

This calculation determines the change in hotel carbon emissions and utility costs resulting from the use of an EnerG 405 unit, producing 405 kWe and 606 kWt for every 1344 kW of gas (Appendix 12.26, page 165). As with the calculations in Appendix 12.15 (page 128) and Appendix 12.16 (page 132) it is assumed that the unit will run at a constant rate of 720 hours per month. The increase in CHP electricity production relative to the base case is used to determine the new electrical consumption by assuming that each kWh of CHP electricity displaces one kWh of grid electricity. The increase in heat production from the CHP unit is assumed to reduce the boiler gas demand, assuming a boiler thermal efficiency of 80% in line with the heat demand calculations in Appendix 12.6 (page 112). The resulting changes in consumption can be summarised in Table 28.

Month, 2007	Power Demand (kWh)	Heat Demand (kWh)	Gas Consumption (kWh)	Grid Electricity Consumption (kWh)	CHP Generated Electricity (kWh)	CHP Generated Heat (kWh)	CHP Gas Input (kWh)
January	268,982	304,222	817,138	-22,618	291,600	436,320	967,680
February	241,677	273,206	776,093	-49,923	291,600	436,320	967,680
March	274,129	284,318	792,486	-17,471	291,600	436,320	967,680
April	270,982	214,097	704,296	-20,618	291,600	436,320	967,680
May	281,679	185,437	668,776	-9,921	291,600	436,320	967,680
June	292,194	235,328	730,953	594	291,600	436,320	967,680
July	303,499	220,220	715,851	11,899	291,600	436,320	967,680
August	309,996	260,607	765,024	18,396	291,600	436,320	967,680
September	416,452	225,753	720,826	124,852	291,600	436,320	967,680
October	294,075	226,808	725,012	2,475	291,600	436,320	967,680
November	266,705	227,674	721,739	-24,895	291,600	436,320	967,680
December	270,199	240,390	742,758	-21,401	291,600	436,320	967,680

Table 28 – Gas and Electricity Demand if EnerG 405 CHP Unit is Installed

It can be seen that a number of the grid electricity consumption values are negative. In these cases, it is assumed that the CHP unit is able to export the electricity generated back to the grid.

The new grid electrical consumption can be allocated on an hourly pro-rata basis to give the day/night electrical consumption split shown below in Table 29.

Month, 2007	Grid Electricity Consumption, Day (kWh)	Grid Electricity Consumption, Night (kWh)
January	-16,021	-6,597
February	-35,362	-14,561
March	-12,375	-5,096
April	-14,604	-6,014
May	-7,027	-2,894
June	421	173
July	8,428	3,471
August	13,031	5,366
September	88,437	36,415
October	1,753	722
November	-17,634	-7,261
December	-15,159	-6,242

Table 29 – Summary of Split Between Day Rate and Night Rate Electricity Consumption if EnerG 405 CHP Unit is Installed

Assuming water demand remains the same as in Appendix 12.1 (page 105); the new values can be used along with the per-unit utility charges originally described in Appendix 12.9 (page 118) to obtain a new figure for the total annual expenditure on utilities. For electricity exported back to the grid, it is assumed that the hotel receives a £0.02/kWh reduction from their electricity bills. The full calculation is shown in Table 30.

Month, 2007	Water (£)	Gas (£)	Grid Electricity, Day (£)	Grid Electricity, Night (£)	CHP Generated Electricity (£)	Total Utility-related Costs (£)
January	£1,803	£19,938	-£320	-£132	£5,832	£27,120
February	£1,521	£18,937	-£707	-£291	£5,832	£25,292
March	£1,831	£19,337	-£248	-£102	£5,832	£26,650
April	£1,779	£17,185	-£292	-£120	£5,832	£24,384
May	£1,817	£16,318	-£141	-£58	£5,832	£23,769
June	£1,794	£17,835	£29	£7	£5,832	£25,497
July	£2,262	£17,467	£587	£133	£5,832	£26,280
August	£2,100	£18,667	£907	£206	£5,832	£27,711
September	£2,022	£17,588	£6,155	£1,398	£5,832	£32,996
October	£2,376	£17,690	£122	£28	£5,832	£26,048
November	£1,838	£17,610	-£353	-£145	£5,832	£24,782
December	£2,471	£18,123	-£303	-£125	£5,832	£25,999
Total (£)	£23,615	£216,695	£5,436	£799	£69,984	**£316,529**

Table 30 – Breakdown of Utility Costs at Case Study Hotel if EnerG 405 CHP Unit is Installed

Assuming water demand would remain identical, the revised figures for gas and electrical consumption taken from Table 28 (page 136) can be used with the carbon conversion factors originally described in Appendix 12.8 (page 116). It is assumed that excess electricity exported from the hotel to the grid helps reduce the overall carbon footprint of the building. The revised figures for the carbon footprint of the hotel are as shown below in Table 31.

Month, 2007	Water (kgCO2)	Gas (kgCO2)	Grid Electricity (kgCO2)	Total Utility-related Emissions (kgCO2)
January	888	168,331	-12,146	157,072
February	749	159,875	-26,810	133,815
March	902	163,252	-9,382	154,772
April	877	145,085	-11,072	134,889
May	895	137,768	-5,328	133,335
June	884	150,576	319	151,779
July	1,114	147,465	6,390	154,969
August	1,034	157,595	9,879	168,508
September	996	148,490	67,048	216,534
October	1,171	149,352	1,329	151,852
November	905	148,678	-13,369	136,215
December	1,217	153,008	-11,493	142,733
Total (kgCO2)	11,633	1,829,476	-4,635	1,836,474

Table 31 – Calculation of Utility-Related CO2 Emissions if EnerG 405 CHP Unit is Installed

Overall, relative to the base case, annual expenditure on utilities falls slightly from £316,809 to £316,529, a saving of 0.1%. At the same time, annual utility-related carbon emissions fall from 2,242,180 kgCO2 to 1,836,474 kgCO2, an 18% saving.

12.18 Calculation for Lamp Replacement Energy Savings

This calculation determines the carbon and utility-cost savings the could potentially derived from replacing a number of lamps at the case study hotel with lower wattage equivalents. Currently the atrium and guest room circulation areas are lit by 400 individual 75W lamps. These are on constantly all year round. The annual energy consumption of these lamps can be calculated in joules and then converted into kWh using the following assumptions:

- Number of lamps: 400
- Lamp Rating: 75 watts
- Hours per Year: 8760 hours
- Seconds per Hour: 3600 seconds
- Joules per kWh: 3600000 joules
- Power Factor of Electrical Installation: 0.95 lagging

This gives an annual electrical consumption of 276,632 kWh for the base case. Applying the same calculation but using 50W lamps gives an annual electrical consumption of 184,421 kWh. The difference between the two is the annual energy saved by moving from 75W lamps to 50W lamps – 92,211 kWh. This can be expressed as an average monthly energy saving of 7,684 kWh.

It was calculated in Appendix 12.10 (page 121) that the CHP unit contributes 44% of the hotel's electrical power, with the remaining 66% coming from the grid. The average monthly energy saving of 7,684 kWh was applied on a pro-rata basis between the base case electrical and CHP energy consumption figures to give the values in Table 32.

Month, 2007	Grid Electricity Consumption (kWh)	CHP Generated Electricity (kWh)
January	161,588	98,941
February	114,653	118,571
March	123,597	142,079
April	155,250	107,279
May	160,185	113,041
June	182,282	101,459
July	159,850	135,196
August	163,988	137,555
September	269,279	138,720
October	146,230	139,392
November	174,231	84,021
December	116,359	145,387
Annual Total	1,927,491	1,461,646
Monthly Average	160,624	121,804

Table 32 – Electricity Demand if Lamp Replacement Exercise is Carried Out

Compared with the base case figures in Appendix 12.1 (page 105), this equates to a 2.1% reduction in grid electrical consumption, a 4% reduction in CHP electricity consumption, and an overall electrical energy saving of 5%.

The new grid electrical consumption can be allocated on an hourly pro-rata basis to give the day/night electrical consumption split shown below in Table 33.

Month, 2007	Grid Electricity Consumption, Day (kWh)	Grid Electricity Consumption, Night (kWh)
January	114,458	47,130
February	81,213	33,440
March	87,548	36,049
April	109,969	45,281
May	113,464	46,721
June	129,116	53,166
July	113,227	46,623
August	116,158	47,830
September	190,739	78,540
October	103,580	42,650
November	123,414	50,817
December	82,421	33,938

Table 33 – Summary of Split Between Day Rate and Night Rate Electricity Consumption if Lamp Replacement Exercise is Carried Out

Assuming water and gas demand remains the same as in Appendix 12.1 (page 105); the new values can be used along with the per-unit utility charges originally described in Appendix 12.9 (page 118) to obtain a new figure for the total annual expenditure on utilities, as shown in Table 34.

Month, 2007	Water (£)	Gas (£)	Grid Electricity, Day (£)	Grid Electricity, Night (£)	CHP Generated Electricity (£)	Total Utility Related Costs (£)
January	£1,803	£13,114	£10,702	£2,149	£1,979	£29,746
February	£1,521	£12,769	£7,593	£1,525	£2,371	£25,780
March	£1,831	£13,955	£6,093	£1,384	£2,842	£26,105
April	£1,779	£10,639	£7,654	£1,739	£2,146	£23,957
May	£1,817	£9,813	£7,897	£1,794	£2,261	£23,583
June	£1,794	£11,095	£8,987	£2,042	£2,029	£25,946
July	£2,262	£9,792	£7,881	£1,790	£2,704	£24,428
August	£2,100	£13,134	£8,085	£1,837	£2,751	£27,906
September	£2,022	£10,077	£13,275	£3,016	£2,774	£31,164
October	£2,376	£11,626	£7,209	£1,638	£2,788	£25,638
November	£1,838	£10,236	£8,590	£1,951	£1,680	£24,295
December	£2,471	£12,767	£5,736	£1,303	£2,908	£25,185
Total (£)	£23,615	£139,016	£99,702	£22,168	£29,233	**£313,733**

Table 34 – Breakdown of Utility Costs at Case Study Hotel if Lamp Replacement Exercise is Carried Out

Compared with the base case figures in Appendix 12.1 (page 105), this equates to a £3076 annual saving, representing 1% of the total annual expenditure on utilities.

Assuming water and gas demand would remain identical; the revised figures for electrical consumption taken from Table 32 can be used with the carbon conversion factors originally described in Appendix 12.8 (page 116). This gives a revised figure for the carbon footprint of the hotel as shown below in Table 35.

Month, 2007	Water (kgCO2)	Gas (kgCO2)	Grid Electricity (kgCO2)	Total Utility Related Emissions (kgCO2)
January	888	110,713	86,776	198,377
February	749	107,801	61,571	170,122
March	902	117,817	66,374	185,092
April	877	89,822	83,372	174,071
May	895	82,851	86,023	169,768
June	884	93,670	97,889	192,443
July	1,114	82,667	85,843	169,624
August	1,034	110,882	88,065	199,981
September	996	85,074	144,608	230,678
October	1,171	98,158	78,528	177,857
November	905	86,419	93,566	180,890
December	1,217	107,784	62,487	171,488
Total (kgCO2)	11,633	1,173,657	1,035,101	2,220,392

Table 35 – Calculation of Utility-Related CO2 Emissions if Lamp Replacement Exercise is Carried Out

Compared with the base case figures in Appendix 12.1 (page 105), this equates to a saving of 21,788 kgCO2, representing 1% of the hotel's annual carbon dioxide emissions.

12.19 Calculation for Bathroom Mirror Heater Energy Savings

This calculation seeks to quantify the financial and environmental benefit that could potentially be obtained from modifying the operation of the bathroom mirror heaters which are installed in the guest bedrooms at the case study hotel. At present the bathroom mirror heaters are linked to the operation of the door access system, and are in operation all year round. The amount of energy saved from changing from a 12 month regime to a 6 month regime can be calculated using the following assumptions:

- Number of Guest Bedrooms with Mirror Heaters: 200
- Mirror Heater Rating: 60 watts
- Average Room Occupancy Hours per Day: 10 hours
- Number of Days in 12 Months: 365 days
- Number of Days in 8 Months: 182.5 days
- Seconds per Hour: 3600 seconds
- Joules per kWh: 3600000 joules
- Power Factor of Electrical Installation: 0.95 lagging

For the 12 month regime, the annual electrical consumption of the mirror heaters is calculated as 46,105 kWh. For the 6 month regime, the energy consumed is 23,053 kWh. The annual energy saved is therefore 23,053 kWh, which is equivalent to 1,921 kWh per month.

It was calculated in Appendix 12.10 (page 121) that the CHP unit contributes 44% of the hotel's electrical power, with the remaining 66% coming from the grid. Applying the average monthly energy saving of 1,921 kWh on a pro-rata basis to the base case figures in Appendix 12.1 (page 105) gives the figures in Table 36.

Month, 2007	Grid Electricity Consumption (kWh)	CHP Generated Electricity (kWh)
January	164,124	102,745
February	117,189	122,375
March	126,133	145,883
April	157,786	111,083
May	162,721	116,845
June	184,818	105,263
July	162,386	139,000
August	166,524	141,359
September	271,815	142,524
October	148,766	143,196
November	176,767	87,825
December	118,895	149,191
Annual Total	1,957,921	1,507,290
Monthly Average	163,160	125,608

Table 36 – Electricity Demand if Mirror Heater Operation is Modified

Compared with the base case figures in Appendix 12.1 (page 105), this equates to a 0.5% reduction in grid electrical consumption, a 1% reduction in CHP electricity consumption, and an overall electrical energy saving of 0.7%.

The new grid electrical consumption can be allocated on an hourly pro-rata basis to give the day/night electrical consumption split shown below in Table 37.

Month, 2007	Grid Electricity Consumption, Day (kWh)	Grid Electricity Consumption, Night (kWh)
January	116,254	47,869
February	83,009	34,180
March	89,344	36,789
April	111,765	46,021
May	115,261	47,460
June	130,913	53,905
July	115,023	47,363
August	117,954	48,569
September	192,535	79,279
October	105,376	43,390
November	125,210	51,557
December	84,217	34,678

Table 37 – Summary of Split Between Day Rate and Night Rate Electricity Consumption if Mirror Heater Operation is Modified

Assuming water and gas demand remains the same as in Appendix 12.1 (page 105); the new values can be used along with the per-unit utility charges originally described in Appendix 12.9 (page 118) to obtain a new figure for the total annual expenditure on utilities, as shown in Table 38.

Month, 2007	Water (£)	Gas (£)	Grid Electricity, Day (£)	Grid Electricity, Night (£)	CHP Generated Electricity (£)	Total Utility Related Costs (£)
January	£1,803	£13,114	£10,870	£2,183	£2,055	£30,024
February	£1,521	£12,769	£7,761	£1,559	£2,448	£26,057
March	£1,831	£13,955	£6,218	£1,413	£2,918	£26,334
April	£1,779	£10,639	£7,779	£1,767	£2,222	£24,186
May	£1,817	£9,813	£8,022	£1,822	£2,337	£23,812
June	£1,794	£11,095	£9,112	£2,070	£2,105	£26,176
July	£2,262	£9,792	£8,006	£1,819	£2,780	£24,658
August	£2,100	£13,134	£8,210	£1,865	£2,827	£28,135
September	£2,022	£10,077	£13,400	£3,044	£2,850	£31,394
October	£2,376	£11,626	£7,334	£1,666	£2,864	£25,867
November	£1,838	£10,236	£8,715	£1,980	£1,757	£24,525
December	£2,471	£12,767	£5,862	£1,332	£2,984	£25,415
Total (£)	£23,615	£139,016	£101,288	£22,519	£30,146	**£316,583**

Table 38 – Breakdown of Utility Costs at Case Study Hotel if Mirror Heater Operation is Modified

Compared with the base case figures in Appendix 12.1 (page 105), this equates to a £225 annual saving, representing 0.07% of the total annual expenditure on utilities.

Assuming water and gas demand would remain identical; the revised figures for electrical consumption taken from Table 36 can be used with the carbon conversion factors originally described in Appendix 12.8 (page 116). This gives a revised figure for the carbon footprint of the hotel as shown below in Table 39.

Month, 2007	Water (kgCO2)	Gas (kgCO2)	Grid Electricity (kgCO2)	Total Utility Related Emissions (kgCO2)
January	888	110,713	88,138	199,739
February	749	107,801	62,933	171,483
March	902	117,817	67,736	186,454
April	877	89,822	84,734	175,433
May	895	82,851	87,384	171,130
June	884	93,670	99,251	193,805
July	1,114	82,667	87,204	170,986
August	1,034	110,882	89,427	201,343
September	996	85,074	145,970	232,039
October	1,171	98,158	79,890	179,219
November	905	86,419	94,927	182,252
December	1,217	107,784	63,849	172,850
Total (kgCO2)	11,633	1,173,657	1,051,443	2,236,733

Table 39 – Calculation of Utility-Related CO2 Emissions if Mirror Heater Operation is Modified

Compared with the base case figures in Appendix 12.1 (page 105), this equates to a saving of 5,447 kgCO2, representing 0.24% of the hotel's annual carbon dioxide emissions.

12.20 Calculation for Mini-Bar Energy Savings

This calculation aims to establish the extent to which utility costs and carbon dioxide emissions from the case study hotel can be reduced through the use of more efficient mini-bar refrigerators in the hotel guest rooms. The energy consumption of the current mini-bar installation was calculated using typical vapour-compression cooling refrigerator specifications, based on the units shown in Appendix 12.27 (page 166), and using the following assumptions:

- Number of Guest Bedrooms with Mini-Bars: 200
- Mini-Bar Energy Consumption: 0.9 kWh/24h
- Number of Days in 1 Year: 365 days
- Power Factor of Electrical Installation: 0.95 lagging

This gives an annual electrical consumption of 69,158 kWh in the base case. Applying the same calculation but using more efficient mini-bar units based on peltier cooling technology, as shown in Appendix 12.28 (page 167) gives an annual energy consumption of 34,579 kWh. These units consume only 0.45 kWh/24h each (rather than 0.9 kWh/24h) and have a similar stocking capacity for drinks as the conventional units (22 facings vs. 24 facings). The annual energy saved is therefore 34,579 kWh, which can be expressed as 2,882 kWh per month.

It was calculated in Appendix 12.10 (page 121) that the CHP unit contributes 44% of the hotel's electrical power, with the remaining 66% coming from the grid. Applying the average monthly energy saving of 2,882 kWh on a pro-rata basis to the base case figures in Appendix 12.1 (page 105) gives the figures in Table 40.

Month, 2007	Grid Electricity Consumption (kWh)	CHP Generated Electricity (kWh)
January	163,701	102,111
February	116,766	121,741
March	125,710	145,249
April	157,363	110,449
May	162,298	116,211
June	184,395	104,629
July	161,963	138,366
August	166,101	140,725
September	271,392	141,890
October	148,343	142,562
November	176,344	87,191
December	118,472	148,557
Annual Total	1,952,849	1,499,683
Monthly Average	162,737	124,974

Table 40 – Electricity Demand if Mini-Bars Replaced with More Efficient Units

Compared with the base case figures in Appendix 12.1 (page 105), this equates to a 0.8% reduction in grid electrical consumption, a 1.5% reduction in CHP electricity consumption, and an overall electrical energy saving of 1.1%.

The new grid electrical consumption can be allocated on an hourly pro-rata basis to give the day/night electrical consumption split shown below in Table 41.

Month, 2007	Grid Electricity Consumption, Day (kWh)	Grid Electricity Consumption, Night (kWh)
January	115,955	47,746
February	82,709	34,057
March	89,045	36,665
April	111,466	45,898
May	114,961	47,337
June	130,613	53,782
July	114,724	47,239
August	117,655	48,446
September	192,236	79,156
October	105,076	43,267
November	124,910	51,434
December	83,918	34,554

Table 41 – Summary of Split Between Day Rate and Night Rate Electricity Consumption if Mini-Bars Replaced with More Efficient Units

Assuming water and gas demand remains the same as in Appendix 12.1 (page 105); the new values can be used along with the per-unit utility charges originally described in Appendix 12.9 (page 118) to obtain a new figure for the total annual expenditure on utilities, as shown in Table 42.

Month, 2007	Water (£)	Gas (£)	Grid Electricity, Day (£)	Grid Electricity, Night (£)	CHP Generated Electricity (£)	Total Utility Related Costs (£)
January	£1,803	£13,114	£10,842	£2,177	£2,042	£29,977
February	£1,521	£12,769	£7,733	£1,553	£2,435	£26,011
March	£1,831	£13,955	£6,198	£1,408	£2,905	£26,296
April	£1,779	£10,639	£7,758	£1,762	£2,209	£24,148
May	£1,817	£9,813	£8,001	£1,818	£2,324	£23,774
June	£1,794	£11,095	£9,091	£2,065	£2,093	£26,137
July	£2,262	£9,792	£7,985	£1,814	£2,767	£24,620
August	£2,100	£13,134	£8,189	£1,860	£2,815	£28,097
September	£2,022	£10,077	£13,380	£3,040	£2,838	£31,356
October	£2,376	£11,626	£7,313	£1,661	£2,851	£25,829
November	£1,838	£10,236	£8,694	£1,975	£1,744	£24,487
December	£2,471	£12,767	£5,841	£1,327	£2,971	£25,377
Total (£)	£23,615	£139,016	£101,024	£22,461	£29,994	£316,108

Table 42 – Breakdown of Utility Costs at Case Study Hotel if Mini-Bars Replaced with More Efficient Units

Compared with the base case figures in Appendix 12.1 (page 105), this equates to a £700 annual saving, representing 0.22% of the total annual expenditure on utilities.

Assuming water and gas demand would remain identical; the revised figures for electrical consumption taken from Table 40 can be used with the carbon conversion factors originally described in Appendix 12.8 (page 116). This gives a revised figure for the carbon footprint of the hotel as shown below in Table 43.

Month, 2007	Water ($kgCO_2$)	Gas ($kgCO_2$)	Grid Electricity ($kgCO_2$)	Total Utility Related Emissions ($kgCO_2$)
January	888	110,713	87,911	199,512
February	749	107,801	62,706	171,256
March	902	117,817	67,509	186,227
April	877	89,822	84,507	175,206
May	895	82,851	87,157	170,903
June	884	93,670	99,024	193,578
July	1,114	82,667	86,977	170,759
August	1,034	110,882	89,200	201,116
September	996	85,074	145,743	231,813
October	1,171	98,158	79,663	178,992
November	905	86,419	94,700	182,025
December	1,217	107,784	63,622	172,623
Total ($kgCO_2$)	11,633	1,173,657	1,048,719	2,234,009

Table 43 – Calculation of Utility-Related CO2 Emissions if Mini-Bars Replaced with More Efficient Units

Compared with the base case figures in Appendix 12.1 (page 105), this equates to a saving of 8,171 kgCO2, representing 0.36% of the hotel's annual carbon dioxide emissions.

12.21 Calculation for Combined Demand Side Reduction Energy Savings

This calculation determines the financial and environmental benefits that can be obtained from combining together a number of different demand side energy reduction measures at the case study hotel. Combining together the energy savings from the demand side energy management strategies described in Appendix 12.18 (page 140), Appendix 12.19 (page 145) and Appendix 12.20 (page 150) gives a total annual saving of 149,842 kWh. This is equivalent to 12,487 kWh per month.

It was calculated in Appendix 12.10 (page 121) that the CHP unit contributes 44% of the hotel's electrical power, with the remaining 66% coming from the grid. Applying the average monthly energy saving of 12,487 kWh on a pro-rata basis to the base case figures in Appendix 12.1 (page 105) gives the figures in Table 44.

Month, 2007	Grid Electricity Consumption (kWh)	CHP Generated Electricity (kWh)
January	159,475	95,772
February	112,540	115,402
March	121,484	138,910
April	153,137	104,110
May	158,072	109,872
June	180,169	98,290
July	157,737	132,027
August	161,875	134,386
September	267,166	135,551
October	144,117	136,223
November	172,118	80,852
December	114,246	142,218
Annual Total	1,902,133	1,423,609
Monthly Average	158,511	118,634

Table 44 – Electricity Demand if All Demand Side Reduction Measures Implemented

Compared with the base case figures in Appendix 12.1 (page 105), this equates to a 3.4% reduction in grid electrical consumption, a 6.5% reduction in CHP electricity consumption, and an overall electrical energy saving of 4.7%.

The new grid electrical consumption can be allocated on an hourly pro-rata basis to give the day/night electrical consumption split shown below in Table 45.

Month, 2007	Grid Electricity Consumption, Day (kWh)	Grid Electricity Consumption, Night (kWh)
January	112,961	46,513
February	79,716	32,824
March	86,051	35,433
April	108,472	44,665
May	111,968	46,104
June	127,620	52,549
July	111,730	46,007
August	114,661	47,213
September	189,242	77,923
October	102,083	42,034
November	121,917	50,201
December	80,924	33,322

Table 45 – Summary of Split Between Day Rate and Night Rate Electricity Consumption if All Demand Side Reduction Measures Implemented

Assuming water and gas demand remains the same as in Appendix 12.1 (page 105); the new values can be used along with the per-unit utility charges originally described in Appendix 12.9 (page 118) to obtain a new figure for the total annual expenditure on utilities, as shown in Table 46.

Month, 2007	Water (£)	Gas (£)	Grid Electricity, Day (£)	Grid Electricity, Night (£)	CHP Generated Electricity (£)	Total Utility Related Costs (£)
January	£1,803	£13,114	£10,562	£2,121	£1,915	£29,515
February	£1,521	£12,769	£7,453	£1,497	£2,308	£25,548
March	£1,831	£13,955	£5,989	£1,361	£2,778	£25,914
April	£1,779	£10,639	£7,550	£1,715	£2,082	£23,766
May	£1,817	£9,813	£7,793	£1,770	£2,197	£23,391
June	£1,794	£11,095	£8,882	£2,018	£1,966	£25,755
July	£2,262	£9,792	£7,776	£1,767	£2,641	£24,237
August	£2,100	£13,134	£7,980	£1,813	£2,688	£27,715
September	£2,022	£10,077	£13,171	£2,992	£2,711	£30,973
October	£2,376	£11,626	£7,105	£1,614	£2,724	£25,446
November	£1,838	£10,236	£8,485	£1,928	£1,617	£24,104
December	£2,471	£12,767	£5,632	£1,280	£2,844	£24,994
Total (£)	£23,615	£139,016	£98,380	£21,875	£28,472	**£311,358**

Table 46 – Breakdown of Utility Costs at Case Study Hotel if All Demand Side Reduction Measures Implemented

Compared with the base case figures in Appendix 12.1 (page 105), this equates to a £5451 annual saving, representing 1.7% of the total annual expenditure on utilities.

Assuming water and gas demand would remain identical; the revised figures for electrical consumption taken from Table 44 can be used with the carbon conversion factors originally described in Appendix 12.8 (page 116). This gives a revised figure for the carbon footprint of the hotel as shown below in Table 47.

Month, 2007	Water (kgCO2)	Gas (kgCO2)	Grid Electricity (kgCO2)	Total Utility Related Emissions (kgCO2)
January	888	110,713	85,641	197,243
February	749	107,801	60,436	168,987
March	902	117,817	65,239	183,958
April	877	89,822	82,238	172,936
May	895	82,851	84,888	168,634
June	884	93,670	96,754	191,308
July	1,114	82,667	84,708	168,489
August	1,034	110,882	86,930	198,846
September	996	85,074	143,473	229,543
October	1,171	98,158	77,394	176,722
November	905	86,419	92,431	179,755
December	1,217	107,784	61,352	170,353
Total (kgCO2)	11,633	1,173,657	1,021,484	2,206,774

Table 47 – Calculation of Utility-Related CO2 Emissions if All Demand Side Reduction Measures Implemented

Compared with the base case figures in Appendix 12.1 (page 105), this equates to a saving of 35,406 kgCO2, representing 1.6% of the hotel's annual carbon dioxide emissions.

12.22 UK Energy Consumption Benchmarks

Table 48 summarises the data used for comparison purposes.

Building Type	Fossil Fuel Use Due To Space Heating And Domestic Hot Water (kWh/m2)	Electricity Use (kWh/m2)	Total Energy Use Intensity (kWh/m2)
Factories	245	471	716
Hospitals	510	108	618
Prisons	430	135	565
Hotels	430	145	575
Nursing Homes	417	79	496
Retail	185	275	460
Secondary Schools	270	62	332
University Accommodation	201	60	261
Commercial Offices	147	95	242
Community Centers	183	39	222
Warehouses	64	81	145
Government Offices	95	39	134

Table 48 – Energy Consumption Benchmarks for Different Building Types in the United Kingdom

The sources for each energy benchmark are as follows:

- Data for Prisons, Factories, Local Government Offices, Commercial Offices, Retail and Warehouses, taken from Appendix G of IEA DH/CHP Project Annex VII, Report 8DHC-05.01, 'A Comparison of Distributed CHP/DH with Large-Scale CHP/DH' (International Energy Agency District Heating and Cooling Project 2005).

- Secondary Schools data taken from Department For Children Schools and Families, 'Energy and Water Benchmarks for Maintained Schools in England 2002-03', (Department For Children, Schools and Families 2004).

- Hotels data based on consolidated information from ECG036, Energy Efficiency In Hotels (The Carbon Trust 1999).

- Community Centres and University Residential Accommodation based on CIBSE Energy Benchmarks for Public Sector Buildings in Northern Ireland (CIBSE 1999a).

- Hospitals figures based on 'Hospital (Acute)' data taken from CIBSE Guide F: Energy Efficiency In Buildings (CIBSE 2004).

12.23 Potential Negative Impacts of Climate Change on Tourism and Hotel Operators

The hotel sector, both in the UK and elsewhere, stands to lose much from the damaging effects of climate change. The IPCC forecasts a greater than 90% probability 'that hot extremes, heat waves, and heavy precipitation events will continue to become more frequent' and a greater than 66% probability 'that future tropical cyclones (typhoons and hurricanes) will become more intense' (Intergovernmental Panel on Climate Change 2008). Since tourists often seek 'places characterized by gentle temperatures and plenty of sun' which hold low risks in terms of climatic disaster (Gómez Martín 2005), this could result in some destinations seeing lower visitor numbers, with resulting economic consequences for local hotel operators.

Climate change also has the potential to affect the viability of water-intensive hotel operations in some regions, which are dependent on reliable water supplies for many of the services they offer, such as swimming pools, spas and golf courses. One study predicts that by 2025 '5 billion people, out of a total population of around 8 billion, will be living in countries experiencing water stress' (Arnell 1999). Changes in precipitation patterns could mean that the availability of water resources for use in hotels and other leisure sectors becomes severely limited, curtailing their activities.

Many tourist destinations are visited primarily for their wildlife and animal habitats, which are now being placed at risk by climate change. Climate change has the potential, for example, to affect bird migration patterns (New Scientist 2008) and the survival of coral reefs and their associated marine fish species (Crabbe 2008). The disruption of established natural ecosystems which form a major tourism resource could result in lower visitor numbers to some destinations, which will negatively affect the profitability of local hotel enterprises.

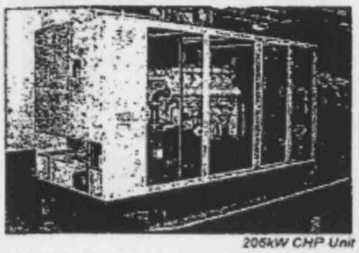
Climate change has the potential to negatively impact hotel owners by affecting peace and stability in regions dependent on tourism for their economic development. Studies have shown that an increased incidence of extreme weather events has the potential to negatively affect crop yields and agricultural production (Adams et al. 2001), as well as being linked to human health and the prevalence of infectious disease outbreaks (Bradbury 2002). Holiday destinations where food is scarce and diseases are prevalent will obviously become less attractive to tourists. Some commentators have raised the prospect of mass human migration as those populations affected by environmental degradation and natural disasters move in search of more favourable conditions. This could lead to increased geopolitical tensions if military force is deployed in order to 'deter or manage the human flows' which could come to be seen as a 'security threat' (Smith 2007) in some countries. Tourists will almost certainly avoid conflict zones and any areas seen as potential flashpoints.

More generally, the future cost of not acting to stabilise the world's climate has the potential to affect the well-being of the global economy as well as the biosphere. The Stern Review, one of the most comprehensive and widely cited references on the potential economic impacts of climate change, famously stated that 'estimates of damage could rise to 20% of GDP or more' (Stern 2006). It is well recognized that 'there is a very clear direct relationship' between economic performance and the volume of demand for holidays and leisure trips (Middleton & Clarke 2001). A world where 20% of GDP is spent on mitigating climate change impacts will be one where less people have disposable income to travel, and where hotel operators could suffer as a result.

12.24 EnerG 206 Small-Scale Packaged CHP Unit, Manufacturer's Datasheet

ENER·G COMBINED POWER

ENER·G 206



205kW CHP Unit

TECHNICAL DATA

General Description	
Fuel Type	Natural Gas
Electrical Output	206kW
Heat Output (@81°C flow)	324kW
Fuel input	683 kW
Min. gas pressure	15 mbar/6ins w.g.
Maximum gas pressure	37.5mbar/15ins w.g.
Max. return water temp	80°C (Full load)
Engine	
Type	MAN E2842
Swept volume	21,930 cm3
Compression ratio	12.5:1
Aspiration	Normal
Gas-Air mixing system	DELTEC
Speed	1500 rev/min
Generator	
Type	Synchronous
Voltage	415V
Full load power factor	0.9
Full load current	332A (230V)
Heat Recovery System	
Integral to unit	Plate Heat Exchanger
Control & Protection System	
Supplied by CPL	DIRMS™

Fuel consumption figures are based on gross calorific value.

Energy quantities subject to reduction when modulating in response to external conditions (eg. reduced heat demand).

Combined Power Limited reserve the right to alter the engine type, without notice, to meet the ENER·G 206 system spec.

Electrical output is based on output at the generator terminals.

Performance figures quoted are subject to original engines manufacturers tolerances.

STANDARD SPECIFICATION

Integral Package

Combined Power Ltd. CHP units offer the most efficient and environmentally friendly way of providing base load heating and electricity resulting in greatly reduced emissions. Each system is supplied as a complete integral package including:

- Industrial engine, battery started
- Synchronous generator coupled to engine
- Base-frame incorporating anti-vibration mounts
- High performance heat recovery system
- Control, protection and monitoring system
- Acoustic Enclosure

Engines

Combined Power Ltd select the most suitable engine for the application from a range of proven industrial gas engines including MAN, Caterpillar, Turbomeca and Perkins. Options include:

- Lean burn combustion - efficient and "green"
- Pre-pressurisation of lube-oil system reduces wear on engine start-up.
- Natural gas, biogas and landfill gas variants available

Generators

- Synchronous - can generate output KVars to help maintain site power factor
- Standby option - combined CHP and emergency genset in one package
- High efficiency
- Single phase failure detector

Heat Recovery System

- Complete with electrically driven primary and secondary pump, necessary valves and controls (Protection against thermal shock)
- "Fully closed" - only the robust main plate heat exchanger is exposed to secondary water
- LPHW, MPHW and steam raising options available
- Automatic heat output modulation for extended running

DIRMS™ *(Distributed Intellect Remote Monitoring & Control System™)*

- Each unit comes complete with Combined Powers unique micro computer based control, protection and monitoring system.
- Control:- engine starting/stopping, synchronising, power out put control including modulation in response to external conditions, compliance with G59 and ETR113
- Protection:- mechanical, electrical and thermal protection ensures unit operates safely
- Monitoring: over 70 parameters are monitored continuously ensuring optimum performance. Data is also logged to provide historical performance information.
- Communication: full 2-way communication is available between each CHP unit and the Combined Power Ltd central maintenance computer - essential for optimum customer care.

Acoustic Enclosure

- 2 options available giving increasing levels of attenuation and providing a clean external appearance
- Standard enclosure - 75 dBA at 1m (free field)
- Upgrade Enclosures - 70dBA at 1m (free field)
- Cost and physical size varies for the upgraded enclosures

Additional (Optional) Features/Equipment on Offer

- External acoustic container packages
- Gas generation packages (no Heat Recovery)
- CHP absorption chiller packages
- BEMS interface card
- Island (emergency genset) operation
- Heat and gas metering
- Export control panel
- Heat Rejection radiators
- Exhaust silencers (industrial & residential grade)
- Anti-vibration support platforms for special applications
- Heat rejection and interface control systems
- Local Display - digital display fitted to the unit giving performance & status information

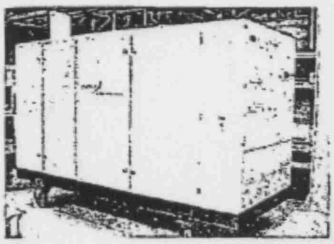
Note: Subject to change due to ongoing R&D

ENER·G House, Daniel Adamson Road, Manchester, M50 1DT Tel: 0161 745 7450 Fax: 0161 745 7457 www.energ.co.uk

12.25 EnerG 305 Small-Scale Packaged CHP Unit, Manufacturer's Datasheet

ENER·G COMBINED POWER

ENER·G 305



305kW CHP Unit

TECHNICAL DATA

General Description	
Fuel Type	Natural Gas
Electrical Output	305 kW
Heat Output (@81°C flow)	432 kW
Fuel input	976 kW
Min. gas pressure	15 mbar/6ins w.g.
Maximum gas pressure	37.5mbar/15ins w.g.
Max. return water temp	80°C (Full load)
Engine	
Type	Perkins 4006TESI LC
Swept volume	22,921 cm3
Compression ratio	9.5:1
Aspiration	Turbocharged/Intercooled
Aftercooler temp	35°C
Gas-Air mixing system	DELTEC
Speed	1500 rev/min
Generator	
Type	Synchronous
Voltage	415V
Full load power factor	0.9
Full load current	491A (230V)
Heat Recovery System	
Integral to unit	Plate Heat Exchanger
Control & Protection System	
Supplied by CPL	DIRMS™

Fuel consumption figures are based on gross calorific value.

Energy quantities subject to reduction when modulating in response to external conditions (eg. reduced heat demand).

Combined Power Limited reserve the right to alter the engine type, without notice, to meet the ENER·G 305 system spec.

Electrical output is based on output at the generator terminals.

Performance figures quoted are subject to original engines manufacturers tolerances.

STANDARD SPECIFICATION

Integral Package

Combined Power Ltd. CHP units offer the most efficient and environmentally friendly way of providing base load heating and electricity resulting in greatly reduced emissions. Each system is supplied as a complete integral package including:

- Industrial engine, battery started
- Synchronous generator coupled to engine
- Base-frame incorporating anti-vibration mounts
- High performance heat recovery system
- Control, protection and monitoring system
- Acoustic Enclosure

Engines

Combined Power Ltd select the most suitable engine for the application from a range of proven industrial gas engines including MAN, Caterpillar, Turbomeca and Perkins. Options include:

- Lean burn combustion - efficient and "green"
- Pre-pressurisation of lube-oil system reduces wear on engine start-up.
- Natural gas, biogas and landfill gas variants available

Generators

- Synchronous - can generate output KVars to help maintain site power factor
- Standby option - combined CHP and emergency genset in one package
- High efficiency
- Single phase failure detector

Heat Recovery System

- Complete with electrically driven primary and secondary pump, necessary valves and controls (Protection against thermal shock)
- "Fully closed" - only the robust main plate heat exchanger is exposed to secondary water
- LPHW, MPHW and steam raising options available
- Automatic heat output modulation for extended running

DIRMS™ *(Distributed Intellect Remote Monitoring & Control System™)*

- Each unit comes complete with Combined Powers unique micro computer based control, protection and monitoring system.
- Control:- engine starting/stopping, synchronising, power out put control including modulation in response to external conditions, compliance with G59 and ETR113
- Protection:- mechanical, electrical and thermal protection ensures unit operates safely
- Monitoring: over 70 parameters are monitored continuously ensuring optimum performance. Data is also logged to provide historical performance information.
- Communication: full 2-way communication is available between each CHP unit and the Combined Power Ltd central maintenance computer - essential for optimum customer care.

Acoustic Enclosure

- 2 options available giving increasing levels of attenuation and providing a clean external appearance
- Standard enclosure - 75 dBA at 1m (free field)
- Upgrade Enclosures - 70dBA at 1m (free field)
- Cost and physical size varies for the upgraded enclosures

Additional (Optional) Features/Equipment on Offer

- External acoustic container packages
- Gas generation packages (no Heat Recovery)
- CHP absorption chiller packages
- BEMS interface card
- Island (emergency genset) operation
- Heat and gas metering
- Export control panel
- Heat Rejection radiators
- Exhaust silencers (industrial & residential grade)
- Anti-vibration support platforms for special applications
- Heat rejection and interface control systems
- Local Display - digital display fitted to the unit giving performance & status information

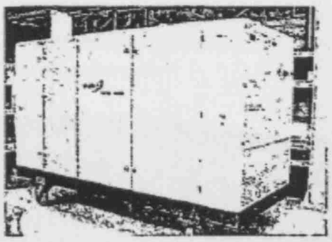
Note: Subject to change due to ongoing R&D

ENER·G HOUSE, Daniel Adamson Road, Manchester, M50 1DT Tel: 0161 745 7450 Fax: 0161 745 7457 www.energ.co.uk

12.26 EnerG 405 Small-Scale Packaged CHP Unit, Manufacturer's Datasheet

ENER·G COMBINED POWER

ENER·G 405



405kW CHP Unit

TECHNICAL DATA

General Description	
Fuel Type	Natural Gas
Electrical Output	405 kW
Heat Output (@81°C flow)	606 kW
Fuel input	1344 kW
Min. gas pressure	15 mbar/6ins w.g.
Maximum gas pressure	37.5mbar/15ins w.g.
Max. return water temp	80°C (Full load)
Engine	
Type	Perkins 4008TESI LC
Swept volume	30,561 cm3
Compression ratio	9.5:1
Aspiration	Turbocharged/Intercooled
Aftercooler temp	35°C
Gas-Air mixing system	DELTEC
Speed	1500 rev/min
Generator	
Type	Synchronous
Voltage	415V
Full load power factor	0.9
Full load current	652A (230V)
Heat Recovery System	
Integral to unit	Plate Heat Exchanger
Control & Protection System	
Supplied by CPL	DIRMS™

Fuel consumption figures are based on gross calorific value.

Energy quantities subject to reduction when modulating in response to external conditions (eg. reduced heat demand).

Combined Power Limited reserve the right to alter the engine type, without notice, to meet the ENER·G 405 system spec.

Electrical output is based on output at the generator terminals.

Performance figures quoted are subject to original engines manufacturers tolerances.

STANDARD SPECIFICATION

Integral Package

Combined Power Ltd. CHP units offer the most efficient and environmentally friendly way of providing base load heating and electricity resulting in greatly reduced emissions. Each system is supplied as a complete integral package including:

- Industrial engine, battery started
- Synchronous generator coupled to engine
- Base-frame incorporating anti-vibration mounts
- High performance heat recovery system
- Control, protection and monitoring system
- Acoustic Enclosure

Engines

Combined Power Ltd select the most suitable engine for the application from a range of proven industrial gas engines including MAN, Caterpillar, Turbomeca and Perkins. Options include:

- Lean burn combustion - efficient and "green"
- Pre-pressurisation of lube-oil system reduces wear on engine start-up,
- Natural gas, biogas and landfill gas variants available

Generators

- Synchronous - can generate output KVars to help maintain site power factor
- Standby option - combined CHP and emergency genset in one package
- High efficiency
- Single phase failure detector

Heat Recovery System

- Complete with electrically driven primary and secondary pump, necessary valves and controls (Protection against thermal shock)
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- LPHW, MPHW and steam raising options available
- Automatic heat output modulation for extended running

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- Protection:- mechanical, electrical and thermal protection ensures unit operates safely
- Monitoring: over 70 parameters are monitored continuously ensuring optimum performance. Data is also logged to provide historical performance information.
- Communication: full 2-way communication is available between each CHP unit and the Combined Power Ltd central maintenance computer - essential for optimum customer care.

Acoustic Enclosure

- 2 options available giving increasing levels of attenuation and providing a clean external appearance
- Standard enclosure - 75 dBA at 1m (free field)
- Upgrade Enclosures - 70dBA at 1m (free field)
- Cost and physical size varies for the upgraded enclosures

Additional (Optional) Features/Equipment on Offer

- External acoustic container packages
- Gas generation packages (no Heat Recovery)
- CHP absorption chiller packages
- BEMS interface card
- Island (emergency genset) operation
- Heat and gas metering
- Export control panel
- Heat Rejection radiators
- Exhaust silencers (industrial & residential grade)
- Anti-vibration support platforms for special applications
- Heat rejection and interface control systems
- Local Display - digital display fitted to the unit giving performance & status information

Note: Subject to change due to ongoing R&D

ENER-G HOUSE, Daniel Adamson Road, Manchester, M50 1DT Tel: 0161 745 7450 Fax: 0161 745 7457 www.energ.co.uk

12.27 Minibar Systems 'Primo' Refrigerator, Manufacturer's Datasheet

PRIMO - great quality, great value

PRIMO minibars have been quality engineered in Switzerland – with generous internal cabinet space, simple and stylish design, low energy consumption and silent absorption technology it's great value for your hotel. PRIMO minibars are available with a 30 or 40 litre cooling unit, interior light and lock as standard and glass door options.

Standard Features

- *Stocking capacity of up to 24 facings*
- *Adjustable transparent door racks for high visibility*
- *Removable shelving for easy cleaning*
- *Thermal insulation manufactured with Cyclopentane*
- *Fully automatic defrost and easily adjustable thermostat*
- *Strong door hinges convertible left to right*
- *All-round magnetic seals to keep the door perfectly shut*
- *Integrated door handles*
- *Interior light*
- *Lock (can be deactivated)*

Technical Specifications

	Primo 30	Primo 40
Gross Volume	30 litre	40 litre
Dimensions HxWxD (mm)	520x400x425	520x400x475
Watts (W)	65 W	65 W
Voltage (V)	220/240	220/240
Energy Consumption (kWh/24h)*	0.85	0.90
Net Weight (kgs)	15.5	16.5
Certification	ISO / TUV / CE / ROHS / WEEE	

Specifications may change without notice due to continuous product development.

* *Average energy consumption over 24 hours period under normal operating conditions*

Ventilation requirements for built-in minibars: *When incorporated into furniture, minibars require proper ventilation (a surface of at least 200 cm2).*

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fax +33 1 47 49 61 62
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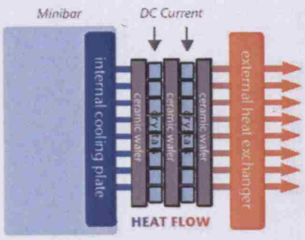
MINIBAR SYSTEMS
smart bars · smart people · smart solutions

12.28 Minibar Systems 'Crystal' Refrigerator, Manufacturer's Datasheet

CRYSTAL - revolutionary technology and efficiency

Thanks to the Peltier technology, the Crystal Minibar has at least 40% lower energy consumption than minibars of similar size.



How does the "Peltier Effect" work?

When a DC current is applied to a Peltier component (see illustration) there is a transfer of heat from one ceramic wafer to the other. Minibar Systems uses two high-quality Peltier components to ensure the best efficiency and minimal energy consumption.

Features

- *Stocking capacity of up to 22 facings*
- *Adjustable door racks and shelving for easy cleaning*
- *Thermal insulation manufactured with Cyclopentane*
- *Fully automatic defrost and easily adjustable thermostat*
- *Strong door seals*
- *Integrated door handle (standard door)*

Options

- *Lock (for glass door)*
- *Interior light*

standard door

glass door (with optional lock)

Technical Specifications

Gross Volume	20 litre	20 litre glass door
Dimensions HxWxD (mm)	475x360x390	475x360x390
Watts (W)	60 W	60 W
Voltage (V)	220/240	220/240
Energy Consumption (kWh/24h)*	0.45	0.75
Net Weight (kgs)	10.5	12.0
Certification	ISO / TUV / CE / ROHS / WEEE	

Specifications may change without notice due to continuous product development.

** Average energy consumption over 24 hours period under normal operating conditions.*

Ventilation requirements for built-in minibars:
When incorporated into furniture, minibars require proper ventilation (a surface of at least 200 cm2).

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www.minibar.ch

MINIBAR SYSTEMS
smart bars • smart people • smart solutions

12.29 UK Department for Environment, Food and Rural Affairs (Defra) Combined Heat and Power Quality Assurance (CHPQA) Programme Certificate for Radisson SAS Liverpool

✓ 13376

CHP QA

defra

Department for Environment Food and Rural Affairs

Quality Certification for an existing CHP Scheme

CHPQA Certificate No: **F03002199**

Scheme: **SAS RADISSON UNIT 792 BEETHAM HOTELS LTD**
101 OLD HALL STREET
LIVERPOOL
MERSEYSIDE
L3 9LQ

CHPQA Scheme Reference No: **5433 A**

This is to Certify that the Self-Assessment of the above CHP Scheme undertaken by **ALISON HEARD** of Scheme performance during the calendar year: **2007** has been Validated under the Combined Heat and Power Quality Assurance programme and that:

1. The Total Power Capacity of this Scheme is:	**0.206** MWe
and the **Qualifying Power Capacity** is:	**0.206** MWe
2. The threshold Power Efficiency criterion for this Scheme is:	**20** %
and the **Power Efficiency** of this Scheme is:	**31.00** %
3. The Qualifying Heat Output from this Scheme is:	**2,361** MWh
and the **Heat Efficiency** of this Scheme is:	**48.08** %
4. The threshold Quality Index criterion for this Scheme under **Annual Operation** is:	**100**
and the **Quality Index** of this Scheme is:	**122.10**
5. The Total Fuel Input to this Scheme is:	**4,911** MWh
and the **Qualifying Fuel Input** is:	**4,911** MWh
6. The Total Power Output from this Scheme is:	**1,523** MWh
and the **Qualifying Power Output** is:	**1,523** MWh

7. The fuel supply reference(s) (e.g. TRANSCO gas meter reference nos. and/or other unique ID descriptors) for this Scheme are:
[TBA]

This certificate is a statement of Scheme performance over the period 01/01/2007 to 31/12/2007 and is valid until 31/12/2008

*Approved by the CHPQA Administrator on behalf of Defra. Date: **15 APRIL 2008***

The CHPQA programme is carried out on behalf of the Department for Environment, Food & Rural Affairs (Defra), in consultation with the Scottish Executive, The National Assembly for Wales, and the Northern Ireland Department of Enterprise, Trade and Investment

For the purposes of the Climate Change Levy (General) (Amendment) Regulations 2003 only, the QPO limit shall be equal to the actual output of the station multiplied by the following ratio: the Qualifying Power Output referred to at item 6 above over the Total Power Output referred to at item 6 above.